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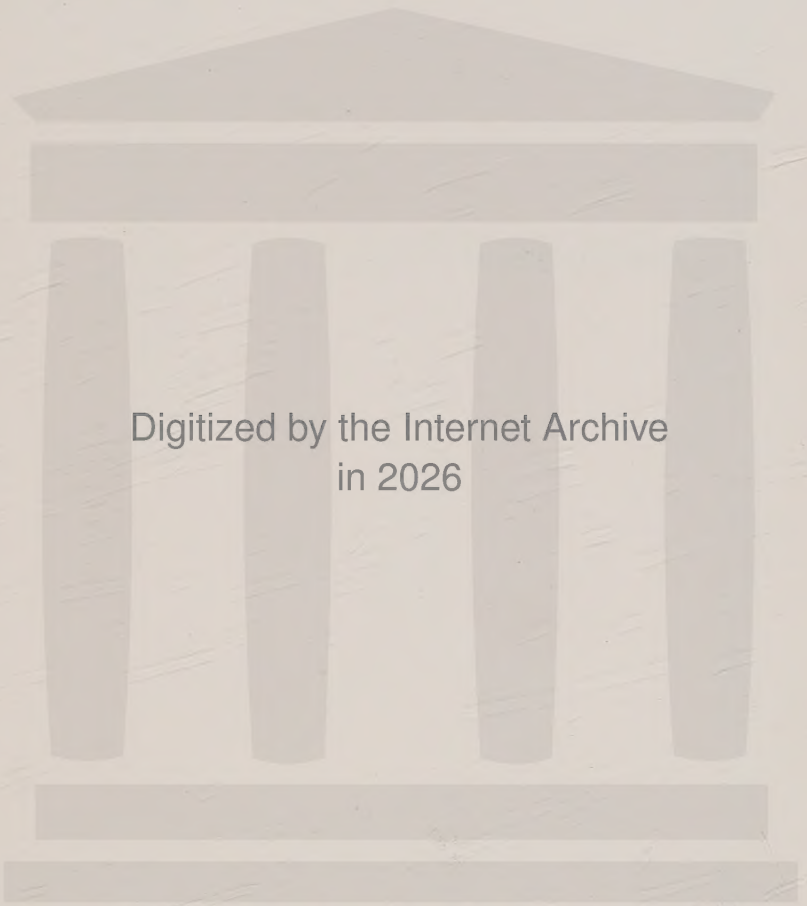
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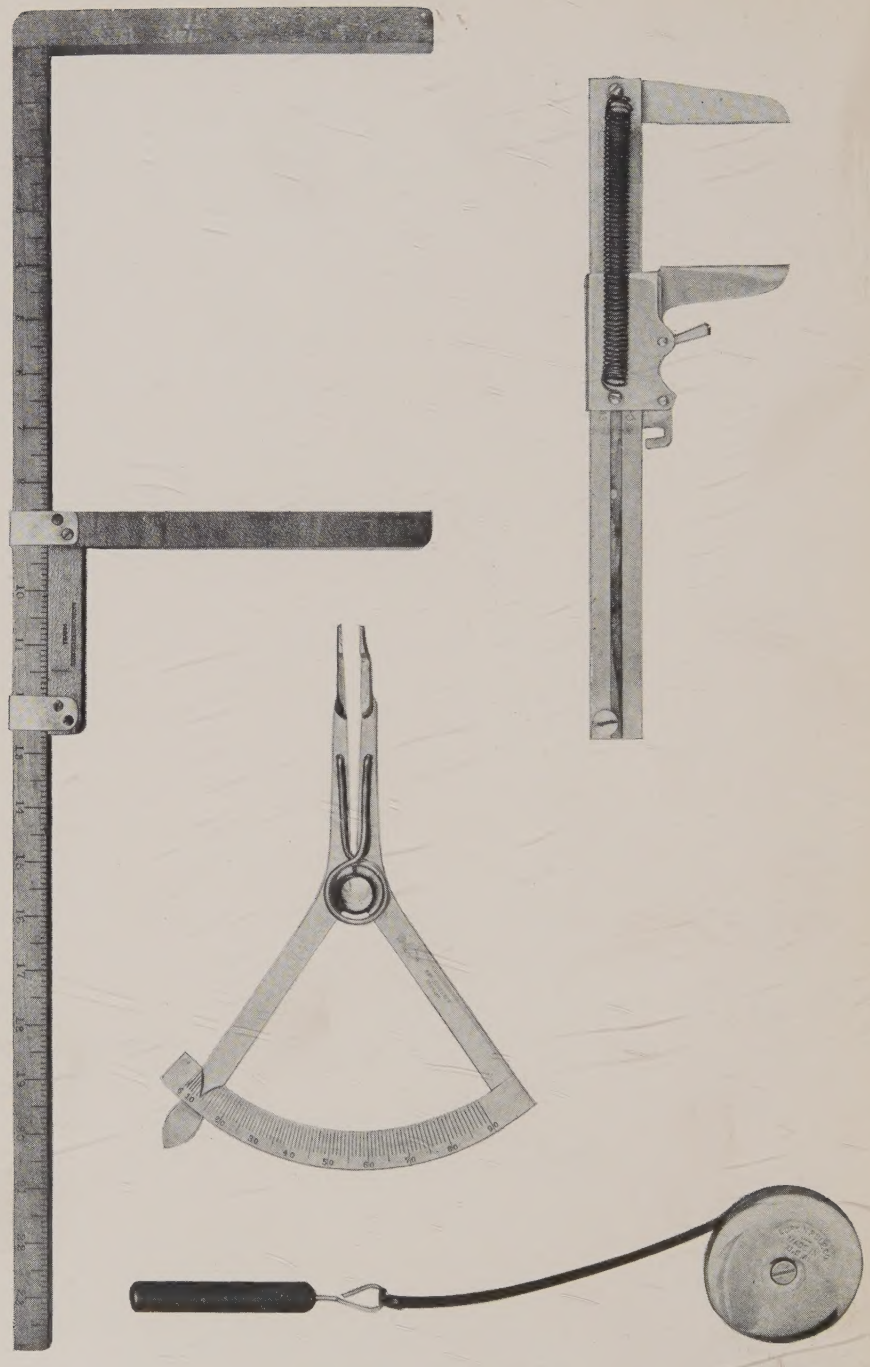

MEASURING INSTRUMENTS

PHYSICAL MEASURES
OF
GROWTH AND NUTRITION

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AMERICAN CHILD HEALTH ASSOCIATION

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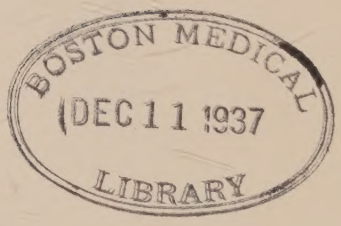

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FOREWORD

This is the second monograph in the School Health Study series. An account of the School Health Study, its objectives and methods, appeared in an introductory chapter of "Health Education Tests," the first monograph of the series. The source material was drawn mainly from field measurements of about 7500 public school children of the fifth and sixth grades in seventy schools of as many cities scattered over thirty-eight states. The measurements and tests were applied by fifteen field workers of the American Child Health Association during the school year 1927-28. Supplementary data were also obtained on other groups of children during the years 1927, 1928, and 1929.

This monograph is devoted to an analysis of the anthropometrical data of the Study in the effort to derive measures in the general field of growth, development, and nutrition. These will be applied together with other analytically derived measures to the seventy schools mentioned above. By comparison of such measures with procedures used in health programs it is hoped to gain knowledge which will aid in the development of school health programs. Evaluations made in the final volume of this series should be materially strengthened by the use of these newly developed quantitative methods.

Though the derivation of a testing method to be used in the Study was the main objective in the work here described, the practical utility of measures for the use of physicians and for routine school use has been kept in mind. This practical use is, of course, delayed. There is no attempt to develop here the actual measures which may be adapted to the needs of school health work. The measures here presented are argued for wholly as research devices. The future will show how much such manners of testing may be adapted to the uses of the pediatrician and others in the school health field. Chapter VI does indicate the direction which an adaptation to school needs will take when and if this proves desirable.

Many formulæ, most of them empirical, have been proposed at various times as indices of nutrition in children. Typical of these are the height-weight-age tables which have had wide use in the schools both as educational material and as a measure of nutrition. This study has in it the elements out of which may arise constructive suggestions leading toward definite improvement in the methods of determining nutrition.

The facts in this report relate to ten-, eleven-, and twelve-year-old American-born white children. They are representative of a population in attendance at city public schools. Excluded from the data are a very few obvious cases of endocrine pathology. Material on lower age groups is available, some of which is presented in Chapter V. These materials have been worked up in the same way as with older age groups but complete presentation of this material is reserved until professional criticism furnishes a better general view of the usefulness of the methodology here developed.

A very great number of basic computations have, of course, been necessary to the findings upon which interpretations have been formed. The amount of error possible in such computations when a usual routine of calculation is used is fully appreciated. As an extra precaution, therefore, independent checks were developed and applied to every separate mathematical computation, and this is explained in Appendix C. By so doing error is believed to have been reduced to altogether negligible proportions. For ease of reading results are expressed for the most part to two decimal places. Computations were made, however, to four places.

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PHYSICAL MEASURES
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Chapter I

MEDICAL JUDGMENT OF NUTRITIONAL STATUS

PROGRESS in the study of hygiene of growth is impeded by many problems which must be solved by quantitative analysis. Analytic measurement should precede definition. At present we may use terms whose meanings hinge upon our objectives instead of having their origin in evidence.

We do, of course, recognize such goals as proper growth, adequate strength, and good nutrition of children, but we are unable to state in exact terms the elements concerned in the occurrence and progress of these conditions. We are, therefore, not able to command the means by which we may arrive at these goals, nor to measure adequately the degree of their attainment. We are even uncertain as to the extent and kind of overlapping existing between various aspects of the desirable conditions of nourishment which we seek.

Three ways in which we may approach the measurement of nutritional status are (1) general estimates of this quality by physicians having clinical experience in this field; (2) detailed reports by physicians, consisting of marking as "satisfactory" or "unsatisfactory" various items, such as amount and quality of subcutaneous tissue, condition of skin, color of mucous membrane, etc. (a score representing the number of satisfactory items might be determined from these details); (3) the construction of objective devices for measuring quantity of each of the qualities involved.

Agreement Between Physicians

To test method (1) above, results of the following procedure were analyzed:

Each of the children in five different groups was seen by a number of physicians (varying from 2 to 7) and rated by each of these

Table 1

CORRELATIONS BETWEEN NUTRITIONAL STATUS RATINGS BY VARIOUS PHYSICIANS

Five Physicians (A, B, C, D, and E) * 29 Cases

Physicians *	A	B	C	D
B	.77			
C	.69	.78		
D	.66	.77	.57	
E	.63	.73	.53	.64

Seven Physicians (F, G, H, I, J, K, and L) † 48 Cases

Physicians	F	G	H	I	J	K
G	.63					
H	.51	.62				
I	.68	.82	.67			
J	.52	.69	.59	.61		
K	.36	.48	.36	.50	.47	
L	.72	.69	.60	.77	.67	.42

Five Physicians (M, N, O, P, and Q) 15 Cases

Physicians	M	N	O	P
N	.70			
O	.61	.59		
P	.41	.45	.36	
Q	.63	.73	.57	.18

Six Physicians (R, S, T, U, V, and W) 100 Cases

Physicians	R	S	T	U	V
S	.66				
T	.64	.71			
U	.47	.52	.49		
V	.57	.51	.52	.43	
W	.64	.69	.50	.34	.55

Two Physicians (X and Y) 61 Cases

Physicians	X
Y	.55

* A, B, C, D, and E are five pediatricians of wide experience.

† Three physicians H, I, K, were used for another group of children below and are the same as S, R, U, respectively. It will be noted that the agreement among these three was approximately the same for both groups of children.

doctors, using an adaptation of the Dunfermline Scale.* These studies involved in all 253 children and 25 physicians. Ratings assigned by each examiner were compared with those assigned to the same group of children by each of the others.

Table 1 gives the fifty-seven correlations thus obtained. The frequency distribution of these correlations is shown in Table 2. The median correlation between any two physicians is .60. Correlations occur as low as .18 and as high as .82.

Table 2

DISTRIBUTION OF THE FIFTY-SEVEN CORRELATIONS IN TABLE 1

Size of Correlation	Frequency
.10 to .19	1
.20 to .29	0
.30 to .39	4
.40 to .49	8
.50 to .59	15
.60 to .69	19
.70 to 79	9
.80 to .89	1

These data allow us to say that when applied to an average group of urban public-school children in this country we cannot expect the ratings of any one physician to agree closely with those of any other. Any two physicians may agree or may not agree, depending upon their training, their beliefs, and the diagnostic emphasis which they give to the various aspects of their judgment. Even a correlation of .60 indicates very low correspondence. With a correlation of this size the chances are very great that a child may receive a low rating from one physician even though he has received a high rating from another.

The disagreements between physicians in ratings given to any

* These ratings were made upon the basis of physical signs following a careful examination. The observations were made at one time and did not consider history or changes that might occur over a period of time. However, these ratings are believed to be representative of the judgments that physicians may make in an office examination without the aid of several periodic observations. The ratings were made in the following terms: 1 = Excellent, 2 = Good, 3 = Fair, 4 = Poor, 5 = Bad.

one child are eight-tenths as large as the individual differences which actually occur.*

Of course, correlations between ratings by groups of physicians, such as the average of any five correlated with the average of another five, are considerably above .90. If it were possible to use the average judgment of five physicians we could be fairly certain that we had an opinion that was representative of physicians as a whole. But the opinion of one physician constitutes our usual clinical rating. The correlation between two physicians represents the objectivity of this clinical rating. Table 2 indicates the degree to which these judgments are free from the personality and individual beliefs, attitudes, and experiences of the physicians who usually make these ratings.

When physicians use forty-six items, each of which is credited as satisfactory or debited as unsatisfactory for each child, the correlation between physicians is still only .65. The examiner is now giving analytic ratings in each of forty-six aspects of nutrition. The child's score now is the number of satisfactory ratings obtained by him. Though the objectivity is low the reliability of this analytic rating plan is high as shown by the fact that correlations between any twenty-three items with the other twenty-three are as follows for six physicians using sixty-one cases:

.99	.96
.97	.95
.97	.90

This indicates that there is a common trend of meaning which holds the units of judgment together for any one examiner even though the judges do not agree with each other. Any one physician registers the same general opinion about a child irrespective of which half of the material is used as the medium through which his opinion is given. If one particular physician says that a child is unsatisfactory on the majority of twenty-three items he is sure to call the child unsatisfactory on most of the other twenty-three as well.

* When r is .6 then $\sqrt{1-r^2}$ is .8. Then the error of estimate which is $\sigma\sqrt{1-r^2}$ is .8 of σ

Judgments which set in motion expensive corrective procedures in the school should certainly be made in such a way that the resulting distinctions between children are not an accident of the physician who happens to make the judgments. If a child is malnourished he should be recognized as malnourished. In order that this be reasonably approximated the correlation between any two physicians should be at least .85. We see from the data in Table 1 that the highest correlation obtained was .82, that it is very common to have correlations between .50 and .70 and that correlations lower than .40 actually occur. Our attempt to improve this objectivity by the use of analytic scales showed that agreement between ratings of physicians is not larger to a significant degree when these ratings are composed of forty-six detailed judgments.

Selection of Items

In order to improve this objectivity, tools and instruments had to be devised. We needed to decide first which aspects of nutrition we would measure. To do this, the results of the ratings of sixty-one cases for the following items by five physicians were analyzed:

I. *Miscellaneous* *

1. Has he marked dark circles under the eyes?
2. Is there unmistakably pale mucous membrane of lower conjunctiva?
3. Is there unmistakably pale mucous membrane inside of cheek?
4. Is there unmistakably pale mucous membrane of lower lip?
5. Is abdomen pot-bellied?
6. Has he winged scapulæ?
7. Is there a well-marked depression above and below clavicle in the supra and infra clavicular space?
8. Has he phlyctenular conjunctivitis?
9. Has he phlyctenular keratitis?
10. Has he lack-luster eyes?
11. Has he dry and dead-appearing hair?

* The medical staff considered from this list all pertinent physical signs occurring in the literature and in the discussions with clinicians following their ratings. Weight, height, and posture were used by the physicians but are not included here because we were already prepared to use objective measures of these qualities.

12. Has he eczema (due to nutritional disturbance)?
13. Has he a markedly dry and roughened skin?
14. Is his skin abnormally pale?
15. Has he a marked worried or anxious expression?
16. Does abdomen approach scaphoid condition?

II. *Muscle—Amount and Quality of Each*

1. Biceps
2. Triceps
3. Thigh
4. Calf
5. Abdomen
6. Back
7. Pectorals
8. Deltoid

III. *Subcutaneous Tissue—Amount and Quality of Each*

1. Over the biceps
2. Over the triceps
3. Over back of thigh (mid part)
4. Over middle and large part of calf
5. Over abdomen two inches to left of umbilicus
6. Over ribs one-half distance between apex beat and costal margin
7. Over mid-point half way between inferior angle of scapula and spinous processes of vertebræ

We were now able to determine the degree to which each of these items was a good index of the total score. This list of items allowed forty-six judgments.* A child might be satisfactory in them all and thus earn a score of 46 or he might be satisfactory in none and thus earn a score of 0. Any score between 46 and 0 was possible. If all of the children who were satisfactory on a given item had high total scores and all of the children who were unsatisfactory on that same item had low total scores, then that was a good item since being satisfactory or unsatisfactory by it alone was representative of being good or bad in total score of items. If, on the other hand, being unsatisfactory in an item, such as, for instance, item 10—"Has he lackluster eyes"—meant that a child might equally well have low or high total score, then, of course, we were able to say his standing in this

* Sixteen miscellaneous items, 16 muscle items, and 14 subcutaneous tissue items.

particular item was no indication of his standing in the test as a whole and, therefore, that item was not a good one to use in this test.

Some of these items fail to qualify in this manner because they are very unobjective. If two physicians clinically observe fifty children and pick out different cases which seem to them to show a "marked worried or anxious expression" (our item 15), or "unmistakably pale mucous membrane inside of cheek" (our item 3), this means that judgments made in either of those traits are accidents of the particular physician rating the child, and are in no sense functions of the child as an organism. They cannot be reliable indices of malnutrition. The following figures show that items 1 to 7 inclusive indicate far too much disagreement between physicians:

Cases Noticed as Unsatisfactory by One of Two Physicians

Item	Per Cent on Which Other Physician Agreed	Per Cent on Which Other Physician Disagreed
1	2	98
2	20	80
3	0	100
4	0	100
5	33	67
6	10	90
7	17	83

Items 8 to 16 inclusive indicate an equal amount of unobjectivity, but the occurrence of unsatisfactory ratings in each of these items is so rare as to make these physical signs impractical as measures. Each of the items from 9 to 16 inclusive occurs in less than one per cent of the cases.

The total scores of those who were unsatisfactory in any of the first sixteen items and the total scores of those who were satisfactory in these same items were practically identical. Many cases who were unsatisfactory in any one of these items had higher total scores than others who were satisfactory in that item. On the other hand, the items representing amount and quality of muscle and those representing amount and quality of subcutaneous tissue had a true relation to total

score. Table 3 gives amounts showing the relative value of these items in respect to the way they differentiate the satisfactory from the unsatisfactory groups in terms of total score. The figures under the star in the table indicate the power of the item. If, being satisfactory in the item makes it very probable that the child will receive favorable ratings in many items, then the amount here will be high (over 1.0). Table 3 presents only the best twenty items. When the amounts in Table 3 are 1.5 or over we may say without hesitation that these items, when scored satisfactory or unsatisfactory, truly divide a group of children as they are divided by the total score of all the items used.

Table 3

STANDARD DIFFERENCES IN AVERAGE OF SATISFACTORY GROUP MINUS UNSATISFACTORY GROUP FOR THE BEST TWENTY ITEMS

Item	*
Amount of Muscle over the Thigh	3.75
Amount of Muscle over the Biceps	3.13
Amount of Muscle over the Triceps	3.12
Amount of Muscle over the Abdomen	2.79
Amount of Muscle over the Calf	2.38
Amount of Subcutaneous Tissue over the Triceps	2.30
Amount of Muscle over the Pectorals	2.29
Amount of Muscle over the Deltoid	2.17
Quality of the Biceps	1.97
Amount of Subcutaneous Tissue over the Abdomen	1.82
Quality of Subcutaneous Tissue over the Ribs	1.66
Amount of Subcutaneous Tissue over the Biceps	1.64
Amount of Subcutaneous Tissue over the Calf	1.60
Quality of Calf Muscle	1.60
Amount of Subcutaneous Tissue over the Back	1.58
Quality of Subcutaneous Tissue over the Biceps	1.55
Amount of Subcutaneous Tissue over the Thigh	1.47
Quality of the Deltoid	1.44
Quality of the Triceps	1.43
Quality of the Subcutaneous Tissue over the Abdomen	1.41

* These are $M_1 - M_2$ divided by the σ of this difference. They are explained in Appendix C–2.

Facts in Table 3 led us to choose for measures of muscle size the biceps, triceps, calf, deltoid, thigh, and abdomen. For practical reasons involved in the examination of children we eliminated the thigh

and the abdomen from this list. Facts in Table 3 prompted us also to choose for the measurement of the amount and quality of subcutaneous tissue the areas over the biceps, triceps, and calf. The prevalence of the use of height-weight tables in relation to nutrition led us to include weight and various skeletal measures in our selection of items for which we desired to build tests. The skeletal elements were chosen by finding the relation of various skeletal characteristics to weight and picking that combination which would best represent the influence that body build has upon weight.* These elements are height, bisacromial width, breadth of chest, depth of chest, and inter-trochanter breadth.

Adequacy of Elements Chosen

From a consideration of these data we made a selection of twelve anthropometric characteristics for use as indices of growth and nutrition. This selection considers, of course, that some of the conditions listed, such as phlyctenular conjunctivitis or winged scapulæ, would in the more typical cases be so characterized as to provide a basis for agreement between physicians and a relation to total score. However, the relation to nutrition is not always clear in these conditions and the unobjectivity of judgments in the numerous cases that are borderline and not typical justifies the decision to eliminate such items from this study.

A description of the method and technique developed for the measurement of the chosen items may be found in Appendix A. The usual methods of measuring height and weight were found to be objective. We proceeded to experiment with calipers and tape in order to find objective methods of testing the other ten measurements in the following list:

1. Weight
2. Height
3. Shoulder Width

* The material for this preliminary exploration was furnished to us by the Elizabeth McCormick Memorial Fund. We were allowed access to the original data reported in "An Investigation of the Health of School Children." The multiple correlation technique was used to provide the necessary facts.

4. Breadth of Chest
5. Depth of Chest
6. Width of Hips
7. Size of Deltoid Muscle
8. Girth of Upper Arm
9. Girth of Calf
10. Amount of Subcutaneous Tissue over the Biceps
11. Amount of Subcutaneous Tissue over the Triceps
12. Amount of Subcutaneous Tissue over the Calf

We shall, before final validation of these materials, need to substantiate our assumptions that these elements are objective and important. We also need to show that the measures chosen are actually symptoms of a quality with a larger application. Thus the two measures of girth and the size of deltoid should, in order to be valuable, indicate the degree to which children have large muscles in general. In this chapter, however, we are attempting to prove only that those measures chosen do include all factors which have an effect on the total rating given by physicians. We desire here to prove that a consideration of these measures is at least as good in quality as the ratings of a competent physician, and that they are, in addition, objective. They will then give indices which will agree with the judgments of groups of physicians and will eliminate those differences in rating which occur because of personality, training, or prejudice of any particular individual.

Table 4 presents the correlations obtained between our selected characteristics and the ratings of each of eleven physicians.* The same table gives also the average relation of the judgments of each of these physicians with the others used in conjunction with him. A comparison of these figures shows that in every case the physician agrees with a composite of our measures more nearly than he agrees with his colleagues.† The differences between these two types of agree-

* This is the correlation of the rating with the best composite of the measured characteristics. Statistical justification will be found in Appendix C–3.

† His agreement with his colleagues is represented by the average of the correlations his ratings have with those of the other physicians. As a further strengthening of this point it may be noted that in only one instance was a correlation between two physicians higher than that between either of the two and the composite of the twelve anthropometric traits.

ment are large and important in the first section of Table 4 which is made up of five experienced pediatricians. We conclude, therefore, that the elements selected and objectified by us do actually include those aspects of medical judgment upon which there is any agreement in actual ratings made by physicians.

Table 4

MULTIPLE CORRELATIONS BETWEEN PHYSICIANS' RATINGS AND COMBINATIONS OF ANTHROPOMETRIC CHARACTERISTICS

When physicians' ratings were combined the average of these ratings was used, the "judgment of physicians" being considered as only one variable no matter how many judgments were used.

Twenty-nine Boys		
Clinical Judgment of Physician	Multiple R with Muscle Size and Amount of Subcutaneous Tissue *	Average of Correlations with Other Physicians
A	.84	.69
B	.98	.76
C	.78	.64
D	.77	.66
E	.68	.63
A, B, C, D, and E	.86	
F, G, H, I, J, K, and L	.84	

One Hundred Boys		
Clinical Judgment of Physician	Multiple R with All Twelve Characteristics	Average of Correlations with Other Physicians
R	.71	.60
S	.69	.62
T	.65	.57
U	.62	.45
V	.66	.52
W	.73	.54

* The measures of "Muscle Size" were (1) deltoid, (2) girth of upper arm, (3) girth of calf. The measures of "Amount of Subcutaneous Tissue" were (1) over the biceps, (2) over the triceps, and (3) over the calf.

Diagnostic Emphasis

Having decided upon the aspects of physical measurement to be considered as minutiæ of our judgment the question naturally arises

as to the manner in which these elements should be weighted. What manner of combining these measurements gives the best final estimate of normal growth? One answer to this question is that they should be weighted so as to obtain a rating for a child which most nearly will approximate the combined rating of a representative group of physicians competent in this field. Another possibility is to use the emphases found dominant in their judgments and to add to them objective measurements which they attempt to utilize but which fail to register as influences in their ratings due either to the complexity of the material involved or to the unobjectivity of the observations.

Consideration of these alternatives led us to obtain mathematically the diagnostic emphasis placed by each of the physicians upon each of the elements selected by us. This means that we found the emphasis to be ascribed to each of our elements in order to obtain the best total correlation with any given physician. The figures in Table 5 give the results of this investigation.*

The coefficient used to gain the best multiple relation for any one element is very different for the various physicians. Emphasis given to weight varies from .10 to .68. Emphasis given to breadth of chest varies from .08 to .32. Emphasis given to girth of upper arm varies from —.07 to .30. Emphasis given to amount of subcutaneous tissue over the biceps varies from —.35 to .10. The standard score coefficients presented in this table are conclusive evidence that the basis of ratings given to children by any one physician is quite different from that employed in ratings by any other. This, of course, is one of the reasons why unobjectivity of ratings, as presented in Table 1 and Table 2, occurs.

Our first alternative for the determination of emphasis fails to qualify on account of wide discrepancies between physicians. There is also a second objection to this way of solving our problem in that the weighting given to amount of subcutaneous tissue (when negative and positive emphases are both considered) is practically zero for

* These emphases are measured by the β's which are coefficients of standard scores in the multiple regression equation. See Kelley "Statistical Method." Proper quotation will be found in Appendix C–4.

Table 5

DIAGNOSTIC EMPHASIS OF EACH OF TWELVE ANTHROPOMETRIC TRAITS IN THE CLINICAL RATINGS OF EACH OF SIX PHYSICIANS *

(One Hundred Boys)

Anthropometric Traits †	Physicians R	S	T	U	V	W
Weight	.10	.34	.57	.12	.68	.20
Height	—.39	—.36	—.44	.25	—.61	—.46
Bisacromial Width	—.12	.02	—.09	—.22	—.11	—.11
Breadth of Chest	.28	.14	.13	.32	.08	.19
Depth of Chest	—.13	—.16	—.03	—.05	.01	—.30
Width of Hips	—.12	—.10	.05	—.25	.00	.22
Size of Deltoid	.32	.32	.22	.33	.21	.03
Girth of Upper Arm	.26	.16	—.02	.13	—.07	.30
Girth of Calf	.40	.18	.26	—.02	.14	.28
Amount of Subcutaneous Tissue over Biceps	—.10	—.17	—.35	—.05	.10	.01
Amount of Subcutaneous Tissue over Triceps	.06	.32	.23	.07	.06	.21
Amount of Subcutaneous Tissue over Calf	—.13	—.11	—.12	.00	—.05	—.04
Multiple Correlation of Physician's Rating with These Twelve Traits	.71	.69	.65	.62	.66	.73
Average of Correlations with Other Physicians	.60	.62	.57	.45	.52	.54

* Mathematical methods used will be found in Appendix C–3, 4.
† Measured as described in Appendix A.

all but one of the physicians studied. This means that in arriving at a total rating the amount of subcutaneous tissue over the biceps, triceps, and calf plays a negligible part. We know that physicians do desire to have the amount of subcutaneous tissue bear some emphasis in their final judgments. Table 3 shows that this is true since children marked satisfactory in these aspects are also children who receive many satisfactory ratings on a list including all elements suggested by the medical profession. This, of course, does show that children who are considered good in the quality judged are also considered good in amount and quality of subcutaneous tissue. It does not mean, however, that being good in this quality has played a part in determining the final rating. Cases called finally good may as an afterthought be judged as good in adipose tissue also.

The reason for estimates of "satisfactory" on items involving the quantity and quality of subcutaneous tissue may be the opinion on the part of the physicians that cases who are good (judged so on a basis of other factors entirely) are also good in this particular aspect and, therefore, rated satisfactory by reason of the general halo of judgment which is operative. Table 3 is then evidence that doctors do believe children who are satisfactory in nutritional status are satisfactory also in subcutaneous tissue. Table 5, on the other hand, is evidence that amount of subcutaneous tissue over the biceps, triceps, and calf (which are the best practical areas in Table 3 also) does not influence in a causal manner the final ratings of physicians. The difference between figures in Table 3 and Table 5 is that, in Table 3 the judgments of amount of adipose tissue were made by the same individuals who made the final rating, whereas in Table 5 the final rating alone was made by the physician and was then correlated with independent objective measures of physical qualities.

For these reasons we chose the other alternative which was to determine our emphases on a basis of what the physicians were attempting to use and what their own opinions showed us they would like to use. Table 5 gives definite evidence that physicians have a tendency to use weight positively, size of muscle positively, and skeletal measurements negatively. Otherwise put, the objective of physicians seems to be to compare children in muscle size and weight within classes of skeletal peers. We believe that though they have failed to compare children in amount of subcutaneous tissue they would like to do this also as represented by data in Table 3. We conclude that measurement of growth and nutritional status involves the consideration of weight, amount of muscle, and amount of subcutaneous tissue, each taken in relation to normal expectancy of these qualities for given skeletal conformation.

Allowance Made by Physicians for Skeletal Characteristics

One of the elements which interferes with a proper adjudication of emphasis in the opinions registered in regard to children by physi-

cians is the failure to make proper allowance for skeletal development. It is the difficulty of making this adjustment which led certain groups to divide children into types and to judge their weight in respect to each type. Variations in the skeletal aspects of growth are distributed in such a way as to throw a serious criticism upon this practice. Our methods of measurement led us to make these adjustments by finding in each case "weight minus the weight to be expected from the skeletal dimensions as actually measured," "actual arm girth minus the arm girth to be expected from actual skeletal components," "actual calf girth minus the calf girth to be expected from the body build as measured," and "actual amount of subcutaneous tissue minus the amount which is normal for the skeletal dimensions of the child measured." We may call these measures *residuals*. A full treatment of their derivation and their value will follow in subsequent chapters. They are, of course, statements of the degree to which children deviate in any stated quality from the amount of that quality which is normal (or expected) for their skeletal peers. The residuals, therefore, make the *proper* allowance for skeletal dimensions.

It is obvious from Table 5 that the physicians have attempted to make some such allowance since this seems the only explanation possible for a negative emphasis assigned to height, bisacromial width, depth of chest, and width of hips. It is apparent also from Table 5 that every one of these physicians failed to give a negative weight to breadth of chest. The large discrepancy amongst physicians in the assignment of these negative emphases increases the conviction that these emphases are not correctly assigned. If the physicians whose opinions are represented in Table 5 did make a proper allowance for skeletal development, then the correlations between their opinions of children and these residuals would be higher than the correlations between their ratings and the gross measures of weight, girth, and amount of subcutaneous tissue.

The reverse is found to be the case. Table 6 gives the correlations of ratings of nutritional status made by these physicians with weight, girths, and amount of subcutaneous tissue taken in and of themselves

without any allowance for skeletal differences. It also gives the correlations that the ratings of these physicians have with weight, girths, and amount of subcutaneous tissue expressed as residuals, which is the correlation when the measure of every child is expressed after proper allowance has been made for his build in a skeletal sense.* It will be seen that the latter set of correlations is much lower than the former.

Table 6

COMPARISON OF CORRELATIONS OF THE RATINGS OF PHYSICIANS WITH MEASURES UNCORRECTED FOR SKELETAL BUILD AND WITH MEASURES SO CORRECTED (RESIDUALS)

Physician	Weight	Weight Residuals	Arm Girth	Arm Girth Residuals	Calf Girth	Calf Girth Residuals	Amount of Subcutaneous Tissue over the Biceps	Amount of Subcutaneous Tissue over the Biceps Residuals
R....	.41	.14	.59	.19	.51	.16	.23	.03
S....	.48	.06	.59	.21	.49	.03	.31	.09
T....	.52	.09	.51	.07	.53	.08	.16	—.02
U....	.50	—.05	.49	.01	.44	.02	.23	—.003
V....	.47	.07	.49	.02	.44	.08	.41	.19
W...	.41	.15	.57	.16	.47	.06	.41	.23

This table gives direct evidence that physicians have failed to make such allowance for skeletal development as they themselves approve and seek to attain. It points directly to the development of objective measures fully analyzed which will fill this need. The remainder of this monograph deals with the derivation of these measures and a full analysis of their validity and use.

Summary

1. Agreement between ratings of nutritional status made by physicians is too small to endorse this form of measurement.
2. An analytic rating scale using forty-six items of judgment does not satisfactorily improve these ratings.

* The formulæ for these calculations appear in Appendix C–6. They are not partial correlations but the correlations of a gross score with a residual.

3. The items of an analytic rating scale in greatest agreement with total judgment are those dealing with amount and quality of muscle and with amount and quality of subcutaneous tissue.
4. The composite of twelve objectified measures agrees more closely with the ratings of any physician than this physician agrees with his colleagues.
5. There is a very wide disagreement in the emphasis bestowed by physicians on each of twelve anthropometric traits.
6. The main emphasis in judgments made by physicians is on weight and muscle size when allowance has been made for skeletal dimensions. The physician wants to use subcutaneous tissue but fails to do so.
7. None of the physicians whose judgments were studied made the proper allowance for skeletal dimensions.

Chapter II

AN ANALYTIC ACCOUNT OF WEIGHT

TABLES 7 and 8 in this chapter and the tables in Appendix B present the original calculations to be elaborated in succeeding chapters. A full description of Table 7 will enable the reader to inspect the others.

Table 7 gives the correlation with weight of each of the eleven characteristics as designated. The figures in the top line labeled "Objectivity" are the correlations of successive measures made independently by two examiners.* The characteristics are arranged from left to right in descending order of the amount of their objectivity. It may be seen that the only measure in which we failed to obtain this quality of objectivity is "Amount of Subcutaneous Tissue over the Calf." This was due to the fact that when the tissue was in particularly firm condition it was difficult to separate it from the muscle in order to adjust the measuring calipers.

The first column of figures in the tables gives the variability † of weight in each of ten sets of children. Each set is composed of 100 children. The sets are arranged from top to bottom in descending order of the amount of their variability. This was done so that the reader might interpret the differences in size of correlations in different sets in terms of the variability in weight of these sets. The wider the spread the larger will be the correlation of any two variables. ‡ Thus the low correlations in a given column tend to be near the bottom of the table.

* See Kelley, "Statistical Method," pp. 221 to 223, section 62. This of course defines the proportion of the variability of the trait which must be ascribed to experimental error. The variability of many measures of the same individual at a time is the group variability times $\sqrt{1-r_1}$ when r_1 is the correlation of two successive measures.

† Variability is expressed as the standard deviation or the root-mean-square of the deviations around the mean.

‡ See Kelley, "Statistical Method," p. 223.

Table 7

CORRELATIONS OF WEIGHT WITH EACH OF ELEVEN TRAITS IN TEN GROUPS OF ONE HUNDRED ELEVEN-YEAR-OLD GIRLS

	Variability of Weight (σ)	Girth of Upper Arm	Girth of Calf	Height	Width of Hips	Size of Deltoid Muscle	Depth of Chest	Bisacromial Width	Amount of Subcutaneous Tissue over the Biceps	Amount of Subcutaneous Tissue over the Triceps	Breadth of Chest	Amount of Subcutaneous Tissue over the Calf	All Eleven Factors Combined Using Multiple Correlation
Objectivity		.99	.99	.99	.98	.96	.96	.94	.94	.94	.91	.65	
Set 1	18	.88	.94	.74	.93	.90	.86	.80	.61	.59	.87	.58	.9863
Set 2	17	.93	.94	.81	.87	.90	.87	.78	.67	.62	.83	.64	.9913
Set 3	17	.92	.86	.77	.85	.88	.85	.77	.66	.56	.83	.53	.9830
Set 4	17	.92	.91	.78	.91	.87	.82	.81	.52	.58	.85	.40	.9831
Set 5	16	.87	.92	.76	.90	.83	.84	.78	.57	.58	.87	.60	.9829
Set 6	15	.86	.90	.82	.90	.78	.78	.73	.61	.51	.82	.58	.9845
Set 7	15	.91	.78	.67	.86	.87	.79	.72	.69	.68	.85	.60	.9792
Set 8	14	.87	.86	.68	.87	.81	.84	.71	.55	.58	.84	.52	.9778
Set 9	14	.89	.93	.67	.83	.84	.79	.44	.57	.53	.75	.61	.9809
Set 10	12	.84	.72	.72	.82	.79	.79	.72	.46	.48	.82	.55	.9708
All 1000	16	.89	.88	.74	.88	.85	.82	.72	.57	.55	.83	.49	.9786
500 A	15	.89	.86	.73	.87	.84	.81	.68	.55	.55	.83	.53	.9760
500 B	16	.89	.90	.76	.88	.86	.83	.76	.61	.57	.83	.48	.9817

Table 8

CORRELATIONS OF WEIGHT WITH EACH OF ELEVEN TRAITS IN TEN GROUPS OF ONE HUNDRED ELEVEN-YEAR-OLD BOYS *

	Variability of Weight (σ)	Girth of Upper Arm	Girth of Calf	Height	Width of Hips	Size of Deltoid Muscle	Depth of Chest	Bisacromial Width	Amount of Subcutaneous Tissue over the Biceps	Amount of Subcutaneous Tissue over the Triceps	Breadth of Chest	Amount of Subcutaneous Tissue over the Calf	All Eleven Factors Combined Using Multiple Correlation
Objectivity		.99	.99	.99	.98	.96	.96	.94	.94	.94	.91	.65	
Set 1	14	.90	.91	.76	.86	.88	.70	.72	.74	.68	.83	.65	.9791
Set 2	14	.93	.88	.71	.86	.83	.85	.80	.69	.63	.88	.54	.9850
Set 3	13	.88	.86	.67	.85	.80	.77	.63	.79	.72	.79	.64	.9804
Set 4	13	.92	.85	.75	.86	.87	.68	.73	.69	.67	.73	.53	.9842
Set 5	13	.86	.88	.69	.74	.77	.67	.73	.62	.60	.74	.41	.9730
Set 6	12	.87	.88	.75	.82	.77	.71	.40	.68	.61	.78	.56	.9784
Set 7	11	.91	.89	.70	.79	.82	.75	.60	.60	.58	.70	.56	.9682
Set 8	11	.82	.85	.77	.87	.75	.62	.76	.60	.58	.75	.40	.9838
Set 9	10	.86	.88	.77	.80	.68	.68	.51	.68	.61	.62	.51	.9775
Set 10	10	.85	.84	.73	.81	.78	.58	.50	.59	.50	.71	.54	.9703
All 1000	12	.88	.87	.72	.82	.80	.71	.63	.66	.61	.76	.50	.9733
500 A	11	.88	.87	.73	.82	.77	.71	.63	.63	.58	.74	.55	.9739
500 B	13	.88	.87	.72	.82	.82	.70	.62	.70	.66	.77	.50	.9759

* Correlation ratios for the most important measures are presented in Appendix C–9.

The last three rows of the table give the correlations for all 1000 cases and those for two random groups of 500 cases each. The close correspondence of the figures in these three rows comprise our assurance that the sampling is adequate. We may say that the conclusions reached from this table hold for any unselected group of American-born girls.*

The last column in the table gives the multiple correlation of all eleven traits with weight.† That is, of course, the relation existing when we have the best possible weighting of each of the component parts. Later portions of this chapter will treat the distribution of diagnostic emphasis which will obtain this highest correlation with weight. The multiples of separate sets in Tables 7 and 8 are consistent to a remarkable degree. This would lead us to conclude that for as delicate a measure as the multiple correlation of eleven variables with one other even as few as 100 cases are an adequate sampling when the measured variables are as reliable as those here reported.

All of the basic eleven-year-old calculations were done in sets of 100 cases similar to those presented in Tables 7 and 8. Tables C and D in Appendix A give all the zero order correlations for 1000 girls and 1000 boys of this age. We have in our files twenty such tables, each representing 100 cases. The similarity of these tables justifies a faith in the adequacy of the sampling and the comparability of materials taken from various portions of the country. Tables 7 and 8 present a portion of this material.

Weight and State of Nutrition

Underweight children have been identified as malnourished children to such an extent that it is well to review the logic of this procedure. When we say that a child is malnourished because he is underweight for his age and height we are ascribing causation of individual

* Using the data for one set of 500 cases exactly the same conclusions are reached as using the other set of 500. The data covered white American-born children all over the country so that each sampling of 500 is random. We may conclude from this that any other random sampling of 500 would yield the same conclusions.

† $R_{1(23\ldots n)} = \sqrt{1-(1-r_{12}^2)(1-r_{13.2}^2)\ldots\ldots\ldots\ldots(1-r_{1n.23}^2\ldots_{n-1}^2)}$

differences in weight over and above age and height to malnutrition. The correlation of height with weight in these data is between .72 and .75. (Tables A, B, C, D, E, and F in Appendix B give r's by age and sex.) Consequently we know there is wide variability in weight for any given height and age. Residuals obtained by subtracting weight usual for a height from actual weight are not indications of state of nourishment nor indeed of any environmental factor but are individual differences in weight due very largely to individual variation in skeletal breadth and depth.

When our score of a child is his deviation in weight from the average weight of his peers in age, height, chest breadth, chest depth, hip breadth, and bisacromial width, then such a deviation represents the result of causes of weight over and above an optimum selection of skeletal dimensions. The correlations of these bony measurements with weight are between .92 and .95 in the six age-sex groups used in this study (Table 9). Comparison of these correlations with those obtained with height alone is conclusive evidence that use of the height-weight tables ascribes to recent history of nourishment much that should be attributed directly to skeletal dimension.

When the deviations are noted from the weight which is to be expected from observed girth of upper arm and calf, size of deltoid, and amount of subcutaneous tissue of biceps, triceps, and calf in addition to the bony measurements mentioned above, we find that they are reduced to a negligible quantity. The correlations with weight are now .97 and .98 in each of the six age-sex groups (Table 12). These multiple correlations are treated in more detail later in this chapter. The variations in weight for children with given values of these eleven anthropometric measures are no larger than are to be expected from influences such as the variations in weight occurring during the day in an individual, differences in clothing, and errors in recording. It would seem therefore that analytic accounting of the elements which together are responsible for weight is possible. It is not necessary to subtract actual weight from weight as it "should be" for given dimensions in order to precipitate other influences. *It*

is better to measure directly the aspects of growth which together account for weight.

Skeletal Determinants of Weight

Table 9 presents the coefficients of five skeletal measurements which result in the combination yielding the highest multiple correlation with weight. They may be viewed as a designation of the relative importance of the five factors as co-determinants of weight.

Table 9

RELATIVE EMPHASIS OF FIVE SKELETAL TRAITS GIVING THE BEST PREDICTION OF WEIGHT *

	Girls			Boys		
Age †	10	11	12	10	11	12
Number of Cases	909	1000	500	788	1000	600
Height	.18	.15	.16	.24	.23	.22
Breadth of Chest	.26	.27	.28	.28	.25	.22
Depth of Chest	.27	.31	.28	.24	.28	.28
Width of Hips	.36	.36	.32	.31	.33	.32
Bisacromial Width	.01	—.004	.05	.05	.04	.06
Multiple Correlation of the Five Traits with Weight	.93	.95	.95	.92	.92	.93

* These, of course, are coefficients of standard scores in the multiple regression equation.

† Age 10 means having passed the tenth birthday but not yet reached the eleventh, etc.

Chart I presents for eleven-year-olds the same facts, reducing the weights to percentage to make the sexes readily comparable. Interpretations of these amounts of emphasis must keep clearly in mind that they each show for one physical trait the unique diagnostic emphasis plus appropriate proportions of the shared influences. There is therefore no overlapping in their expression.

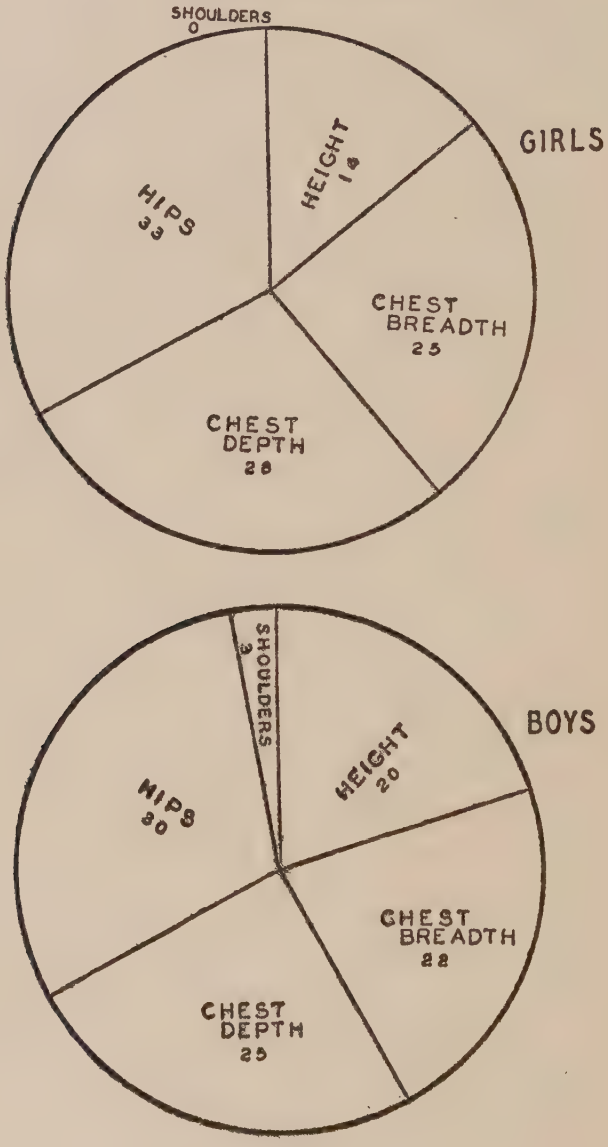
Individual differences in bisacromial width have no significant influence on variations in weight. Its correlation with weight is due to causes represented by the other skeletal dimensions as well. It does not add to the combined influence.

Height is less important than the other three traits. If only one skeletal dimension is used to predict weight it would be far better

Chart I

PROPORTIONATE INFLUENCE UPON WEIGHT OF FIVE SKELETAL DIMENSIONS

(Eleven-Year-Old Children)



to use hips than height. If three are used, hips and the two chest dimensions would give a predicted weight which accounted for a greater part of weight due to bony framework than any combination of three using height.* Since the object of such predictions is for use as a subtrahend to actual weight, thus ridding a weight diagnosis of the portions caused by body build, it is highly important to note the relative importance of these dimensions of skeletal development as determinants of weight.

Sex differences are apparent in Chart I. Chest dimensions play a larger rôle in the determination of the weight of girls than of boys. On the other hand, the height and the shoulder breadth of boys are a larger influence in weight than are those dimensions in girls. (It may be noted that the breadth of shoulders has a greater affinity to height than to any of the other skeletal measurements.) This same sex difference becomes apparent in another way also. For eleven-year-old girls the multiple correlation of both chest dimensions with weight is .90, which is higher than the correlation with weight of height combined with any other measure. For eleven-year-old boys, however, the multiple correlation of both chest dimensions with weight is only .84, which is a lower correlation with weight than for any other combination of two measures (Tables G and H in Appendix B).

An Illustration of Errors Involved in the Use of Height-Weight Ratios

We selected from 1000 eleven-year-old boys those who were just average height for their age (56 inches tall). We distributed these children for weight. Table 10 presents this distribution of 185 boys. According to the Baldwin-Wood Tables these children "should weigh" 77 pounds. Children of this height and age weighing less than 70 pounds are called by some malnourished because they are "10 per cent or more underweight." † There are thirty such children in this

* This will be brought out still more clearly in comparisons of the multiple R's.

† The use of per cent underweight is, of course, mathematically unsound. It assumes that the variability of different ages grows in direct proportion to the average difference of those ages. It is, however, a rule of thumb method for finding the serious deviations in weight for a given height and age. We use it here for ease of comprehension of errors involved in customary usage.

table. Children weighing 92 pounds or more are "20 per cent or more overweight." There are ten such children in this table.

Table 11 is concerned with these two groups that would be selected for observation by common usage. In order to emphasize the situation, we present in Table 11 ten cases that are 15 per cent or more underweight compared with ten cases who are 20 per cent or more overweight. The columns opposite the cases in Table 11 show under appropriate designations percentile positions of these cases in chest and hips when compared with their peers in age and height. For example, Case "a" is 20 per cent below weight judged by the height-weight-age tables. He is below weight because he is skeletally small. Of his peers in height and age 69 per cent have *larger* chest breadth, 99 per cent have *larger* chest depth and 82 per cent have *larger* hip width. All the cases that are underweight are below average for their height and age in chest dimensions and with a single exception in hips, and all of the cases that are overweight are above average in these characteristics with a single exception in hips.

We conclude from Table 11 that cases who are markedly underweight or overweight for their age and height are so merely by virtue of chest dimensions and hips and that, therefore, this method of selection does not adequately serve as an index of nutrition.

Table 10

DISTRIBUTION IN WEIGHT OF ELEVEN-YEAR-OLD BOYS JUST AVERAGE IN HEIGHT

One hundred eighty-five boys, 11 years old and 56 inches tall, all of whom "should weigh" 77 lbs. by height-weight-age table.

Actual Weight in Pounds	Number of Cases
60-65	3
65-70	27
70-75	50
75-80	51
80-85	32
85-90	11
90-95	4
95-100	3
100-105	1
105-110	3

Table 11

SKELETAL INFLUENCES ON UNDERWEIGHT AND OVERWEIGHT

Child	Per cent Underweight by Height-Weight-Age Tables	Per cent of Height-Age Peers having **Larger** Skeletal Measures than Underweight Child in Column at Left. Chest Breadth	Chest Depth	Hips
a	20	69	99	82
b	18	75	75	86
c	18	59	99	69
d	16	97	89	84
e	16	85	54	43
f	15	77	96	69
g	15	77	84	91
h	15	95	88	98
i	15	89	79	98
j	15	77	79	50

Child	Per cent Overweight by Height-Weight-Age Tables	Per cent of Height-Age Peers having **Smaller** Skeletal Measures than Overweight Child in Column at Left. Chest Breadth	Chest Depth	Hips
k	38	98	94	99
l	38	98	99	94
m	37	89	99	95
n	31	99	99	96
o	27	98	89	94
p	26	83	97	99
q	23	86	95	99
r	23	96	97	47
s	21	97	99	98
t	21	63	85	77

Influence on Weight of Eleven Anthropometric Traits

Table 12 presents the coefficients of all eleven measures which result in the combination yielding the highest multiple correlation with weight. It is interesting to note the similarity of the six age-sex groups in regard to the emphasis put on each trait in this best team influence upon weight. The table also implies that in diagnostic significance girth of upper arm and girth of calf are superior as indices of muscle amount to size of deltoid when the objective is a prediction of weight. Size of deltoid adds very little to the correlation with weight when girth of upper arm and calf are already used.

Table 12

EMPHASIS OF ELEVEN ANTHROPOMETRIC TRAITS ON WEIGHT

	Girls			Boys		
Age	10	11	12	10	11	12
Number of Cases	909	1000	500	788	1000	600
Height	.24	.22	.19	.30	.26	.25
Breadth of Chest	.13	.15	.14	.12	.10	.09
Depth of Chest	.10	.11	.11	.08	.08	.10
Width of Hips	.14	.15	.13	.10	.12	.10
Bisacromial Width	.006	—.01	.02	.02	.03	.04
Size of Deltoid Muscle	.05	.06	.03	.01	.04	.002
Girth of Upper Arm	.26	.22	.27	.31	.27	.30
Girth of Calf	.20	.21	.20	.17	.21	.21
Amount of Subcutaneous Tissue over the Calf	—.005	—.02	—.000	.003	—.004	—.01
Amount of Subcutaneous Tissue over the Biceps	.03	.04	.02	.04	.08	.02
Amount of Subcutaneous Tissue over the Triceps	.02	.03	.03	.04	.01	.05
Multiple Correlation with Weight	.9714	.9786	.9806	.9725	.9733	.9666

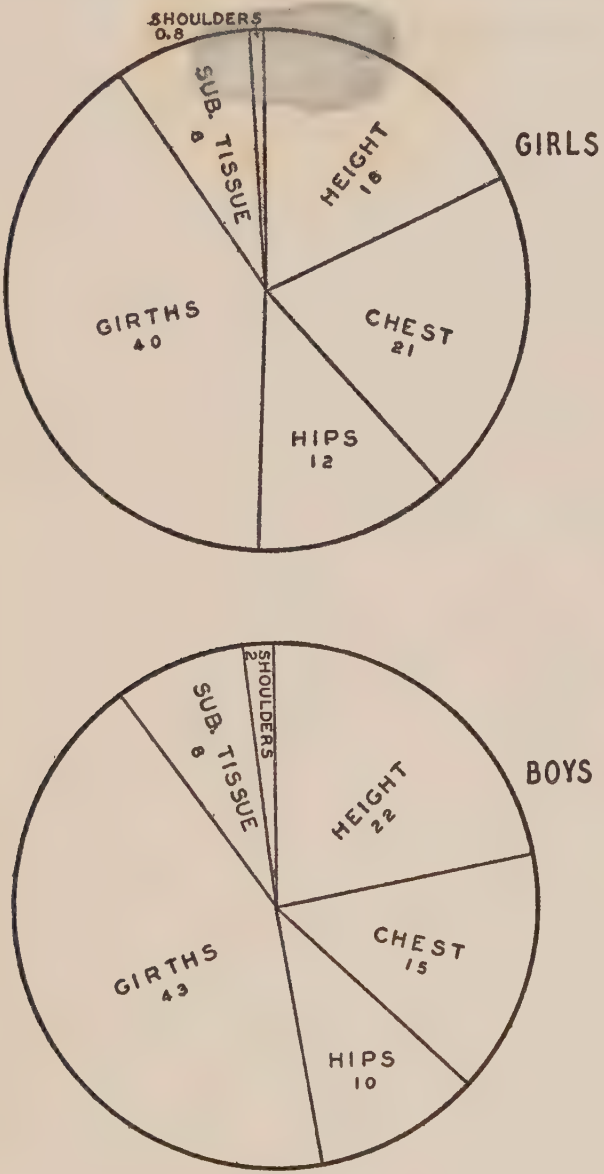
For ease of interpretation we have combined the girth measures and the subcutaneous tissue factors and then reduced these to percentage so that the sexes are more readily comparable. These results appear in Chart II. The large rôle played by girths is immediately apparent. We may also readily appreciate the negligible influence which amount of subcutaneous tissue has upon weight in and of itself. The relative emphasis placed on skeletal measures is different from Chart I because now we present the importance of these elements when used in conjunction with girths. Chest dimensions and hips share the influence which they have upon weight with an influence also represented by girths and therefore become smaller relative to height in this chart.

We shall draw many conclusions from the high multiple correlation of our eleven chosen anthropometric considerations with weight and shall make further reference to the relative emphasis bestowed upon each in their best combined weight-predicting influence. Therefore it seems important to justify the adequacy of our sampling of

Chart II

PROPORTIONATE INFLUENCE UPON WEIGHT OF ITS COMBINED FACTORS

(Eleven-Year-Old Children)



children. Table 13 gives for each sex, facts like those presented in Table 12 computed separately for random halves. We then have the emphasis of each of our traits for any 500 girls (or boys), for another 500, and for the total 1000.* Inspection of this table clearly substantiates our claim that 1000 cases give an adequate age-sex sampling. Although changes do occur in the relative weights of the three muscle-size measures they do not occur in the combined weights of all three. The only trait in which we do find a markedly atypical emphasis for any of the groups is "Amount of Subcutaneous Tissue over the Calf." This is due to the unobjectivity of our measure of this quality which we have already discounted for this reason.

Table 13

EFFECT OF SAMPLING ON THE EMPHASIS OF ELEVEN ANTHROPOMETRIC GROWTH INFLUENCES ON WEIGHT

(Eleven-year-old Children)

	A 500 Girls	B 500 Girls	A + B 1000 Girls	C 500 Boys	D 500 Boys	C + D 1000 Boys
Height	.20	.23	.22	.25	.28	.26
Breadth of Chest	.13	.17	.15	.08	.10	.10
Depth of Chest	.14	.09	.11	.07	.09	.08
Width of Hips	.15	.14	.15	.13	.12	.12
Bisacromial Width	.00	—.02	—.01	.02	.03	.03
Size of Deltoid Muscle	.06	.05	.06	.11	.01	.04
Girth of Upper Arm	.18	.26	.22	.19	.27	.27
Girth of Calf	.25	.18	.21	.16	.22	.21
Amount of Subcutaneous Tissue over the Calf	—.03	—.01	—.02	.15 †	.01	—.004
Amount of Subcutaneous Tissue over the Biceps	.05	.04	.04	.10	.07	.08
Amount of Subcutaneous Tissue over the Triceps	.01	.04	.03	.01	.02	.01
Multiple Correlation with Weight	.9817	.9760	.9786	.9759	.9739	.9733

† This .15 is a spurious result due to chance errors because of the low objectivity of our measurement of subcutaneous tissue over the calf.

* As stated before, we have figures like these for 20 groups of 100 cases, each of which substantiates our claim of adequacy of sampling. This also answers any fears of racial influence.

Relative Influence on Weight of Various Skeletal Combinations

Charts III and IV present graphically (by the heavy lines) correlations and multiple correlations with weight of the fifteen possible combinations of the four chosen skeletal dimensions, arranged in ascending order. The squares of the correlations are used since the value of correlations is in direct proportion to their squares and the comparisons are then adequate.* Tables G and H in Appendix B give the same data in another form.

The bottom line in each chart represents the multiple with weight of the four skeletal measures plus the two girths (upper arm and calf) in order to show the degree to which muscle size adds to the best skeletal prediction of weight. This line represents the prediction value of multiple correlations of .97 with weight in both charts. Using height, chest breadth, chest depth, hips, upper arm girth, and calf girth we may account for all variations in registered weight except those which may reasonably be expected from accidents of elimination, variability in clothes, and errors in recording. The line immediately over it represents the prediction value of a multiple correlation of .94 in Chart III and .92 in Chart IV. These correlations are between the four skeletal dimensions designated and weight. Each of the other lines represents the prediction value of a particular combination of skeletal measurements. All combinations of the four traits selected are given.

Among girls variations in weight within a group *who are peers in these dimensions* may be attributed one half to differences in muscle size and one half to error. The girth influence is greater in boys as shown in Chart IV but here also actual weight minus weight predicted from bony measurements is not a pure diagnosis of girth. It has a share of unexplained causation too large in relation to the known influence of muscle size. *Since we may compare these children directly in terms of muscle size we advise against the use of actual weight minus the weight predicted from four skeletal determinants.*

* Some important mathematical justifications of this statement may be found in Appendix C–7.

Chart III

RELATIVE VALUE OF WEIGHT PREDICTIONS USING VARIOUS COMBINATIONS OF SKELETAL DIMENSIONS

(1100 Girls, Eleven Years Old)

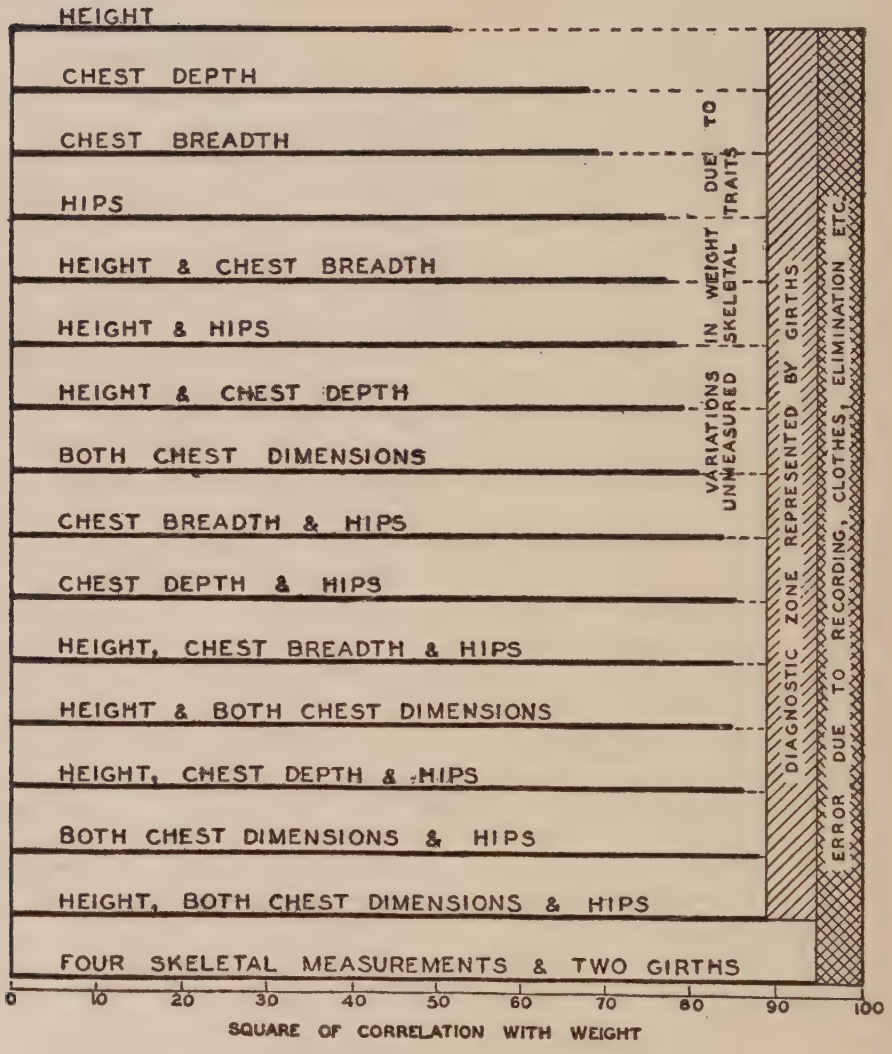
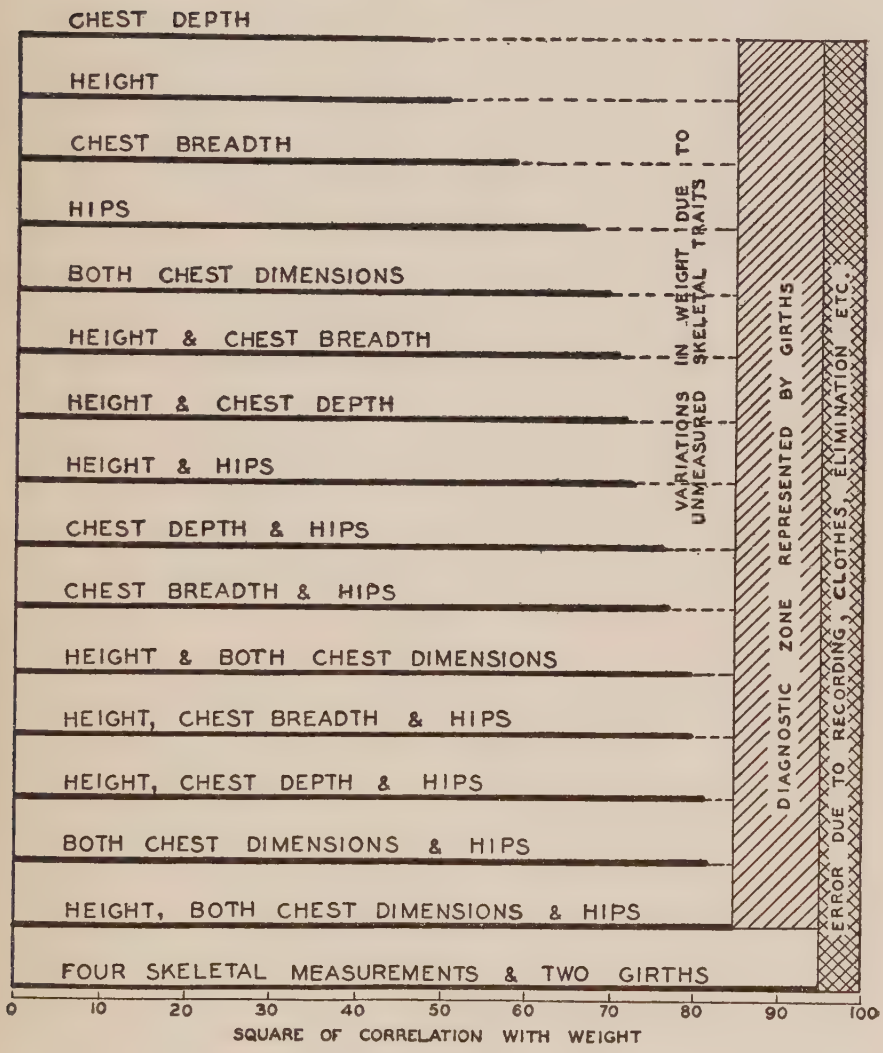


Chart IV

RELATIVE VALUE OF WEIGHT PREDICTIONS USING VARIOUS COMBINATIONS OF SKELETAL DIMENSIONS

(500 Boys, Eleven Years Old)



This objection against the use of the best weight prediction gained by the coöperative use of these four dimensions holds for all other combinations as well. In addition a more serious danger develops. For example, actual weight minus the weight predicted from chest breadth and hips in girls results in individual differences which are due about one-third to other skeletal differences, one-third to differences in muscle size, and one-third to errors of recording, clothes, and elimination. The length of the broken portion of each line in Charts III and IV shows the degree to which residuals from that kind of prediction are due to skeletal characteristics not used in the prediction. The top line in Chart III and the second line in Chart IV show that the actual weight minus weight predicted from height give indices that are due to individual differences in other skeletal dimensions to the extent of six-sevenths in girls and three-fourths in boys.

As far as we may agree that "nutritional status," as we now use the term, shall refer to differences amongst children caused by hygienic influences such as food and sleep habits of immediately preceding years and not to genetic, prenatal, and early growth determinants, we must discard weight in any form as a diagnostic measure. This follows directly from the huge rôle played by skeletal differences in the determination of the variability of weight.

Summary

1. The correlation of height with weight is not nearly as high as the correlation of other skeletal combinations with weight, therefore it seems that height is insufficient skeletal information to use as a basis of weight classification. Individual differences in chest dimensions and hips are even more important as determinants of variations in weight. Being underweight for a given height is very likely to mean small chest and hip dimensions.
2. Experimental results which attribute nutrition conclusions to comparisons of groups in weight-height ratios may be very much in error due to hip and chest variations of the groups.
3. The multiples of five skeletal dimensions with weight are high enough to make unimportant the variation amongst children in weight

when taken only in relation to skeletal peers. If individual differences in weight not due to skeletal differences were an important result of recent history of food, sleep and the expenditure of energy, then the variability of weight amongst children with the same bony build would be much larger than it is.

4. The multiples of all eleven factors with weight are near unity, therefore it seems that practically all the individual variations in weight may be assigned to its measurable components. Analytic statements will show not only that a child is underweight but just *why* he is underweight in terms of other physical traits.
5. Variations in amount of subcutaneous tissue have little relation to variations in weight amongst children who are skeletal peers. Therefore diagnoses based on weight indices neglect this very important factor.
6. The correlations are so high generally as to constitute evidence of a great many common elements but also a subtle but certain balance in which nine or ten elements play an important part. We therefore desire formulæ which will indicate the symmetry of development by measuring a child in each trait in terms of what might be expected from his dimensions in the others.

Chapter III

AN ANALYTIC ACCOUNT OF MUSCLE SIZE AND AMOUNT OF SUBCUTANEOUS TISSUE

CHARTS III and IV in Chapter II show the large weight-predicting increment added to skeletal influences by girths. It follows that when from actual weight of children we subtract the average weight of the skeletal peers of each, the residuals represent to a large degree individual differences in girth of upper arm and calf. This suggests the possibility that the use of muscle size as an index of growth, strength, and nutrition may be a better practice than the use of weight. Weight is an over-all measurement. It represents too much and is especially unworthy because of its high correlation with skeletal components. Girth of upper arm and calf includes a large proportion of that element of weight not represented by bony frame and, in addition, contains other components which probably have important diagnostic significance.

Girth of upper arm and calf are candidates for further consideration also because of their support by clinical opinion. We have seen that medical judgments of nutritional status are strongly preoccupied with quality and quantity of muscle. These are represented by the girth measures.

Common Factor of Muscle Size

The physical traits studied include three which are predominantly muscle size: girth of upper arm, girth of calf, and size of deltoid. There is a common factor in these three measures. Children who have small girth of upper arm tend to be small in the other two measurements also. Children who have average size calf tend also to be average in girth of upper arm and size of deltoid muscle. A very

large deltoid means large muscles in arm and leg. The intercorrelations of these three measurements are between .67 and .86 (Tables A to F in Appendix B).

We have assurance, then, that being large muscled is a feature of the organism and not a set of unrelated qualities in different portions of the body. Recommendations of this chapter will include the use of girth residuals which are obtained for each child by subtracting from actual girth the amount of this quality to be expected by that child's skeletal characteristics. The question now arises whether these residuals for upper arm girth discriminate between children as do these same residuals for calf girth. Otherwise stated this asks the degree to which the common factor in muscle size is due to a common element of arm girth and calf girth which is free from their common relation to bony elements. If the similarity between diagnoses using arm girth and calf girth is due principally to values shared by each with skeletal dimensions, then the partial correlation between the two girths each apart from skeletal measures (which is the correlation between residuals) would be materially smaller than the correlation between the girths when skeletal traits are not excluded. That this is the case is shown by comparing the following figures with the corresponding girth correlations in Tables A to F, Appendix B.

Correlation of Girth of Upper Arm with Girth of Calf Both Irrespective of Height, Depth of Chest, Breadth of Chest, Width of Hips, and Bisacromial Width *

Girls, Ten Years Old	.50
Eleven Years Old	.49
Twelve Years Old	.53
Boys, Ten Years Old	.47
Eleven Years Old	.58
Twelve Years Old	.56

The conclusion reached from this comparison is that we must use both arm girth and calf girth residuals. They are sufficiently dif-

* These correlations are explained in Appendix C–6.

ferent to justify combined usage.* It is appropriate to add that ridding these correlations between the two girths of the common influence of amount of subcutaneous tissue does not further reduce the size of the partial correlations to any significant degree. They reduce less than .05.

Relation of Skeletal Measures to Muscle Size

Tables 14 and 15 give the multiple correlations between the five skeletal measures and each of the two girths. These multiples state the correlation between the combined skeletal measures and the girths when each of the indices of bony development has its optimum weighting. The actual coefficients of each skeletal component appear above the multiples.

Table 14

RELATIVE EMPHASIS OF FIVE SKELETAL TRAITS GIVING THE BEST PREDICTION OF ARM GIRTH

	Girls			Boys		
Age	10	11	12	10	11	12
Number of Cases	909	1000	500	788	1000	600
Height	—.18	—.17	—.11	—.16	—.07	—.13
Breadth of Chest	.27	.26	.31	.30	.28	.24
Depth of Chest	.35	.44	.35	.33	.37	.37
Width of Hips	.40	.35	.33	.38	.33	.40
Bisacromial Width	.03	.02	.05	.08	.03	.06
Multiple Correlation	.81	.85	.86	.80	.81	.85

Table 15

RELATIVE EMPHASIS OF FIVE SKELETAL TRAITS GIVING THE BEST PREDICTION OF CALF GIRTH

	Girls			Boys		
Age	10	11	12	10	11	12
Number of Cases	909	1000	500	788	1000	600
Height	—.005	—.05	.03	.06	.03	.07
Breadth of Chest	.21	.18	.19	.23	.22	.21
Depth of Chest	.27	.32	.27	.25	.27	.27
Width of Hips	.40	.41	.36	.30	.38	.34
Bisacromial Width	.02	.04	.12	.07	.03	.07
Multiple Correlation	.79	.82	.85	.76	.78	.83

* We are at present gathering further material to judge the extent to which a common factor of muscle size residuals may be shown by employing more girth measures.

If these multiple correlations are all lower than those of the same factors with weight it would mean that the skeletal components of weight are greater than those of muscle size. Then the actual weight minus a weight expected by virtue of skeletal dimensions yields residuals far less important than residuals obtained in the same manner for girth. There would in this case be much more opportunity of attributing deviations of actual girth from the girth normal amongst skeletal peers, to influences such as recent conditions of nourishment, rest, and fatigue. The following comparison of multiple correlations shows that portions of weight not due to body build are negligible, but portions of girth not due to skeletal frame are relatively important.

Multiple Correlations of Five Skeletal Measures *

	With Weight	With Arm Girth	With Calf Girth
Girls, Ten Years Old	.93	.81	.79
Eleven Years Old	.95	.85	.82
Twelve Years Old	.95	.86	.85
Boys, Ten Years Old	.92	.80	.76
Eleven Years Old	.92	.81	.78
Twelve Years Old	.93	.85	.83

Relative Influence on Girth of Various Skeletal Combinations

The best prediction of girth from skeletal measures brings certain characteristic emphases of the skeletal components different in one marked respect from the emphases used to predict weight. (Compare Table 9, and Tables 14 and 15.) Height has a negative emphasis in the regression equation for predicting arm girth and a zero emphasis in that equation which gives the best predictions for the girth of calf. This means that height has very little influence on the size of girth. In groups equal in other skeletal traits it makes little or no difference how tall a person is in terms of the expectations of his

* To those not versed in statistics it is appropriate to note that difference between .9 and .8 in correlation is as .44 is to .6 in size of residuals because σ of residuals equals the total σ times $\sqrt{1-r^2}$.

muscle size. In fact in such groups the taller an individual is the less you will expect from him in the way of girth of upper arm. This is, of course, very reasonable. It means that the partial correlation between height and girth, when breadth and depth of frame are constant, is zero or negative. The partial correlation between height and amount of subcutaneous tissue when the other skeletal traits are constant is negative also. (The correlations for eleven-year-old girls and boys respectively are —.17 and —.15 for amount over biceps and —.24 and —.17 for amount over triceps.)

Influence on Girth of Seven Anthropometric Traits

Table 16 gives the multiple correlations with arm and calf girth for eleven-year-old girls of the seven measures which show the best relations throughout. These seven measures leave out of those originally used only subcutaneous tissue over the calf which shows unobjectivity as measured; size of deltoid which has such a large overlapping influence with arm and calf girth as to make its separate use unimportant in this respect; and bisacromial width which is of little

Table 16

COMPARISON OF THE RELATIVE EMPHASIS OF SEVEN ANTHROPOMETRIC TRAITS GIVING THE BEST PREDICTION OF GIRTHS WITH AND WITHOUT THE USE OF WEIGHT AS A FACTOR IN 1100 ELEVEN-YEAR-OLD GIRLS

	Arm Girth		Calf Girth	
	Without Weight	With Weight	Without Weight	With Weight
Height	—.08	—.19	.06	—.10
Breadth of Chest	.16	.03	.07	—.06
Depth of Chest	.26	.14	.08	—.02
Width of Hips	.11	—.01	.22	.05
Girth of Calf	.36	.17	—	—
Girth of Arm	—	—	.53	.25
Amount of Subcutaneous Tissue over the Biceps	.08	.05	—.02	—.04
Amount of Subcutaneous Tissue over the Triceps	.19	.14	.02	.002
Weight	—	.64	—	.77
Multiple Correlation	.92	.93	.87	.89

Table 17

RELATIVE EMPHASIS OF SEVEN ANTHROPOMETRIC TRAITS GIVING THE BEST PREDICTION OF ARM GIRTH

	Girls			Boys		
Age	10	11	12	10	11	12
Number of Cases	909	1000	500	788	1000	600
Height	—.09	—.08	—.09	—.11	—.03	—.11
Breadth of Chest	.17	.16	.20	.19	.14	.14
Depth of Chest	.18	.26	.19	.17	.19	.17
Width of Hips	.13	.11	.12	.16	.08	.18
Girth of Calf	.36	.36	.41	.35	.43	.45
Amount of Subcutaneous Tissue over the Biceps	.10	.08	.06	.16	.11	.17
Amount of Subcutaneous Tissue over the Triceps	.22	.19	.16	.12	.14	.06
Multiple Correlation	.90	.92	.92	.88	.90	.92

Table 18

RELATIVE EMPHASIS OF SEVEN ANTHROPOMETRIC TRAITS GIVING THE BEST PREDICTION OF CALF GIRTH

	Girls			Boys		
Age	10	11	12	10	11	12
Number of Cases	909	1000	500	788	1000	600
Height	.11	.05	.12	.16	.09	.17
Breadth of Chest	.08	.07	.07	.09	.06	.08
Depth of Chest	.11	.08	.07	.08	.05	.04
Width of Hips	.17	.22	.20	.08	.16	.11
Girth of Arm	.51	.53	.53	.51	.55	.60
Amount of Subcutaneous Tissue over the Biceps	—.15	—.02	—.004	—.07	—.008	—.04
Amount of Subcutaneous Tissue over the Triceps	.14	.02	.02	.13	.10	.04
Multiple Correlation	.85	.87	.90	.82	.86	.88

importance as shown in Tables 14 and 15. Table 16 shows the regression values and multiple correlation of these seven characteristics on arm girth and calf girth when the seven measures are used without weight in the combination and when they are used with weight. Tables 17 and 18 give like facts for the other age and sex groups, except that it seemed unnecessary to repeat the facts when weight is used in combination with the other factors.

The coefficients of amount of subcutaneous tissue allow us to say that it is very likely that the degree to which the amount of subcutaneous tissue is correlated with girth is due merely to the manner in which the measurement is taken. We may study this directly by viewing the correlations between amount of subcutaneous tissue and girth, irrespective of bony development. These are as follows:

Correlation of Girth Measures With Measures of Amount of Subcutaneous Tissue Irrespective of the Influence of Bony Development Using Eleven-Year-Old Children

	1000 Girls	1000 Boys
Arm Girth with Subcutaneous Tissue over the Biceps	.46	.46
Arm Girth with Subcutaneous Tissue over the Triceps	.51	.50
Calf Girth with Subcutaneous Tissue over the Biceps	.21	.33
Calf Girth with Subcutaneous Tissue over the Triceps	.26	.39

The very large difference in the size of these partial correlations with arm and calf girth respectively, indicates the degree to which the correlation itself is due to a spurious relation involved in the manner of measurement. When girths are obtained we, of course, also measure individual differences in amount of subcutaneous tissue and, therefore, our more direct caliper measurement is correlated with this when both measures are done in relation to the biceps.

The main facts needing interpretation are:

1. The negligible emphasis of height in the multiples with skeletal measures shown in Tables 14 and 15.*
2. The very slight increase in multiple correlation when weight is used in conjunction with the other factors (Table 16).
3. The relatively small proportional change in co-efficients when the seven factors are used in conjunction with weight from those obtained when the seven factors are used alone (Table 16).
4. The large emphases held by the girths upon each other. This reinforces our conclusions in regard to a common factor existing in our measures of muscle size (Tables 17 and 18).

* When skeletal measures are used in conjunction with arm girth to predict calf girth then height increases its relative importance (Table 18). Because of the negative relation of height to arm girth they are good team-mates in the prediction of calf girth. Each contributes a unique predictive factor to the combination.

These four statements allow us to conclude that actual girth minus predicted girth indicates something which is more than weight. As we have seen in Chapter II, from a dynamic point of view towards growth, weight is the combined resultant of many aspects of development, each of which should be viewed by itself and studied in regard to its own peculiar force. The facts presented in this study make it hard from a scientific point of view for us to understand why we ever did attach diagnostic significance to weight in children of these ages. It is inclusive of so many growth factors which are probably genetic or rooted in early childhood and leaves out the very factors which do portray recent conditions such as rest, food, and consumption of vitality. These neglected factors are amount of girth, irrespective of bony development, and amount of subcutaneous tissue, irrespective of height, chest breadth, chest depth, and hips. The results listed above also allow us to say that the determinants of girth in relation to which we wish to obtain residuals are mainly chest breadth, chest depth, and hips. Height is not a positive factor in the situation (Tables 14 and 15). This indicates again that use of height-weight tables is an incorrect procedure since this negative or zero relationship shows us that we should not expect more girth from tall children than from short ones of the same skeletal breadth and depth, and since this is true of girth it is true also of that part of weight which is associated with girths.

Since height and girth are not positively correlated irrespective of other bony development, we are not led to expect small girths when a child is not tall (unless this shortness is accompanied by lack of breadth and depth) even though we may expect less weight. The partial correlations are:

	1000 Eleven-Year-Old Girls	1000 Eleven-Year-Old Boys
Height with girth of upper arm—with breadth of chest, depth of chest and width of hips constant	—.20	—.07
Height with girth of calf—with breadth of chest, depth of chest and width of hips constant	—.04	.04

When actual weight is subtracted from the average weight for the child's height we attribute to him a weight status which represents the degree to which other causes than height affect his weight. We use the weight appropriate to his height as a norm. This means that we exclude from our consideration the weight deviations caused by height. Thus children who are very short and very light are called normal whether their muscles are large or small. Some of these children are light because of skeletal framework and others are light because they have small muscles. But the fact that they are not tall does not excuse small muscles unless they are small in chest and hips also. Children who are short but are broad and deep are not normal unless they have large muscles. On the other hand, tall children who are underweight for their height often have normal muscles for their skeletal dimensions. They are "underweight" for other reasons than girth. The fact that they are tall does not call for large muscles unless height brings with it concomitant breadth and depth. Height and weight are correlated irrespective of bony breadth and depth, whereas muscle size and height are unrelated, except via their common relations to other skeletal qualities. This means that discrepancies in weight, due to a lack of muscle, are not necessarily shown by weight discrepancies for given heights. Many children underweight for their height have perfectly normal muscle development, since an underweight condition due to girths can only be adequately displayed by comparing with norms, using the causative agents of such girth-weight results. Height brings weight with it in proportion to skeletal breadth and depth but not in proportion to muscle size and amounts of subcutaneous tissue.

It would seem from such facts that actual weight minus readings in a height-weight table had little likeness to actual girth minus the girth to be expected from chest depth and hips. This is portrayed by the correlations between weight irrespective of height with girth irrespective of chest depth and hips. These are with a single exception below .50.

Table 19

CORRELATIONS OF GIRTHS APART FROM CHEST DEPTH AND HIPS WITH WEIGHT APART FROM HEIGHT *

	Arm Girth	Calf Girth
Girls, Ten Years Old	.49	.34
Eleven Years Old	.46	.33
Twelve Years Old	.44	.28
Boys, Ten Years Old	.54	.34
Eleven Years Old	.47	.38
Twelve Years Old	.46	.29

* These are not ordinary partial correlations. See Appendix C–6 for their derivation.

Importance of Measures of Subcutaneous Tissue

We have seen that physicians' ratings of nutritional status are influenced to a great degree by the size and quality of the muscle. This was apparent in Chapter I. In contrast to this, actual clinical ratings correlated against anthropometric measurements show that the amount and quality of subcutaneous tissue has a negligible diagnostic emphasis. Nevertheless, most medical opinions agree that this quality should be an important element in the decision of the nutritional status enjoyed by a child. Our material in Table 3 of Chapter I definitely shows this to be the case.

There are two possible justifications for research attention to certain aspects of anthropometric measurement: (1) Emphasis of the element in clinical judgments as they are really made—illustrated experimentally in Table 5—(2) the agreement of experts that the factor under consideration is an important index of the quality we wish to approximate—illustrated experimentally in Table 3. We have offered the first as one of the reasons for our attention to girths and we offer the second as a basis for further analysis of amount and quality of subcutaneous tissue.* An element of growth which experts agree is an important aspect of nutritional status but which can be

* We use the description "amount and quality" because it is so represented in medical opinion. In all subsequent treatment we shall speak of "amount" alone since we cannot prove that our measurements do include also quality. It may be easily seen, however, from the description in Appendix A that firmness of subcutaneous tissue is involved as well as amount in the measurement with the calipers which we have constructed for this purpose.

shown, nevertheless, to play a very insignificant rôle in their actual judgments of children, is, of course, an element which should be objectified and standardized in order that it may bear the emphasis in medical judgment which the physicians themselves believe that it should have.

Another fact which turns our attention to the measurement of subcutaneous tissue is its low multiple correlation with the best skeletal composite. These multiple correlations are between .52 and .61 for ten-, eleven-, and twelve-year-olds of either sex (Tables 20 and 21). This means that caliper readings of this quality have a wide spread for any given bony structure. Residuals are large when in each case we take the actual caliper reading minus the expectation appropriate to the skeletal measures. We have seen in Chapter I that one of our important reasons for discrediting the use of weight deviation from the norm to be expected from given skeletal dimensions, is that these residuals are very small. Since individual differences observed in skeletal dimension must have causes rooted in early childhood and inheritance and since variability in weight not due to these skeletal differences is small and unimportant, we have concluded that weight cannot represent in an adequate manner the variation in children representative of their immediate history in rest, assimilation of food, and expenditure of energy. The converse of this argument applies to measures of the amount of subcutaneous tissue. Here the actual measures differ in large amounts from the expectations normal to skeletal dimensions. Therefore individual differences in the residuals become important and these can easily be diagnostic of conditions of sleep, food, and exercise immediately preceding the period of measurement.

When selecting several measures which are expected to work as a team in order that they may coöperate in the measurement of some important quality, we desire as much as possible to select items of measurement which supplement each other. We attempt to select indices which do not overlap in meaning so as to minimize the duplication of testing effort. If this caliper reading residual is a valuable

team-mate of the girth residuals treated in the previous chapter, we would expect a low correlation between girth of calf and amount of subcutaneous tissue over the biceps both measured for each child in relation to the skeletal peers of that child.* These correlations are as follows:

Girls,	Ten Years Old	.16
	Eleven Years Old	.21
	Twelve Years Old	.24
Boys,	Ten Years Old	.16
	Eleven Years Old	.33
	Twelve Years Old	.26

We conclude from these partial correlations that residuals of amount of subcutaneous tissue over the biceps distinguish children in a manner which supplements and does not duplicate the discriminations made by girth residuals as treated in Chapter III.

Common Factor in Measures of Subcutaneous Tissue

Two of our three measures of amount of subcutaneous tissue show objectivities of .94, as may be seen in Table 7. The other with an objectivity of only .65 has been eliminated on that account from our considerations. The correlations between amount of subcutaneous tissue over the biceps and amount of subcutaneous tissue over the triceps are as follows:

Girls,	Ten Years Old	.81
	Eleven Years Old	.83
	Twelve Years Old	.82
Boys,	Ten Years Old	.85
	Eleven Years Old	.85
	Twelve Years Old	.85

These are, of course, correlations between our caliper readings as taken. We are anxious to see also the correlation between the resi-

* As mentioned in another portion of this chapter we can only measure this relation by the use of calf girth since the relations of the measures of amount of subcutaneous tissue over the biceps and triceps with girth of upper arm are spurious by definition. Since our measure of amount of subcutaneous tissue over the calf proved unobjective we cannot use this measure in any of our calculations.

duals obtained in each case by subtracting from the actual amount of subcutaneous tissue the amount to be expected of that child by reason of his skeletal components. These partial correlations of the two subcutaneous tissue measurements, irrespective of the five skeletal dimensions, are as follows:

Girls, Ten Years Old	.76
Eleven Years Old	.77
Twelve Years Old	.77
Boys, Ten Years Old	.79
Eleven Years Old	.79
Twelve Years Old	.78

This constitutes definite evidence that the quality "Amount of Subcutaneous Tissue" for given skeletal conformity yields dependable distinctions in children. There is a common factor in the two measures of amount of subcutaneous tissue taken over the biceps and over the triceps, irrespective of any common affinity to bony dimensions. Children who show high negative residuals in one of these measures will show high negative residuals in the other also. The relation between these two measures of subcutaneous tissue remains high even when arm and calf girth, as well as skeletal measures, are held constant. This partial is .71 in the case of eleven-year-old girls.*

This evidence then allows us to believe that there is some common meaning in various measures of amount of subcutaneous tissue which is entirely independent of skeletal measures and girths. Children having a large amount of subcutaneous tissue over the biceps have this general quality in the other area as well even when compared entirely within a group like them in skeletal dimension and in girth of upper arm and calf. We may use the residuals of one of these measures from expectations yielded by bony measurement, with confidence that this quality measures more than an accident of that particular physical location.

* This partial correlation was not figured for any of the other age-sex groups.

Relation of Skeletal Measures to Amount of Subcutaneous Tissue over the Biceps

Tables 20 and 21 portray the relative emphasis of each of our skeletal measures in their best multiple correlation with amount of subcutaneous tissue over the biceps and triceps for ten-, eleven-, and twelve-year-old girls and boys. The low multiple correlations mentioned in the beginning of this chapter are apparent in these tables.

Table 20

RELATIVE EMPHASIS OF FIVE SKELETAL TRAITS GIVING THE BEST PREDICTION OF AMOUNT OF SUBCUTANEOUS TISSUE OVER THE BICEPS

	Girls			Boys		
Age	10	11	12	10	11	12
Number of Cases	909	1000	500	788	1000	600
Height	—.13	—.14	.03	—.16	—.12	—.05
Breadth of Chest	.26	.30	.19	.22	.28	.21
Depth of Chest	.26	.30	.31	.25	.29	.36
Width of Hips	.33	.27	.18	.40	.29	.33
Bisacromial Width	—.21	—.23	—.14	—.09	—.10	—.27
Multiple Correlation	.56	.55	.53	.59	.61	.61

Table 21

RELATIVE EMPHASIS OF FIVE SKELETAL TRAITS GIVING THE BEST PREDICTION OF AMOUNT OF SUBCUTANEOUS TISSUE OVER THE TRICEPS

	Girls			Boys		
Age	10	11	12	10	11	12
Number of Cases	909	1000	500	788	1000	600
Height	—.23	—.24	—.06	—.18	—.16	—.17
Breadth of Chest	.21	.26	.22	.19	.20	.16
Depth of Chest	.16	.20	.19	.16	.20	.27
Width of Hips	.52	.45	.35	.47	.42	.47
Bisacromial Width	—.22	—.22	—.18	—.10	—.12	—.23
Multiple Correlation	.55	.54	.52	.56	.56	.57

The negative emphasis on height and bisacromial width is interesting and instructive. As was the case with the multiple regression

of girths the negative coefficient of height shows that within groups alike in all other skeletal respects the taller one is, the less is the amount of subcutaneous tissue. Unlike the case of girths, bisacromial width, which is so often associated in effect with height, displays here a relation like that of height in size and direction. It will be remembered that the coefficient of bisacromial width, in the case of weight and girths, was to all practical purposes zero. Independent of other skeletal qualities, breadth of shoulders has no relation to either weight or girth of upper arm and calf. In the case of amount of subcutaneous tissue, however, within a group of ten-year-olds who are alike in chest dimensions, width of hips, and height, those who have broad shoulders may be expected to have very little subcutaneous tissue, whereas those who have narrow shoulders will be covered with a much thicker layer of tissue at the biceps and triceps. Tallness alone or breadth of shoulders alone within a group alike in bony width and depth brings an expectation of less subcutaneous tissue than is otherwise characteristic of that bony type and, of course, the two qualities together minimize the normal tissue covering of the muscles.

There is a noticeable difference between the emphases upon width of hips and chest dimensions, in the coefficients of the equations for predicting amount of subcutaneous tissue over the biceps compared with the coefficients in the equations for predicting the amount of subcutaneous tissue over the triceps. The amount of subcutaneous tissue over the biceps is more closely related to chest dimensions in all age and sex groups and amount of subcutaneous tissue over the triceps is more closely related to width of hips in the same groups (Tables 20 and 21). Age and sex differences are treated in another chapter.

We conclude from these materials that useful tables for the judgment of values related to nutritional status should include a table which will predict amount of subcutaneous tissue over the biceps to be expected from any combination of the five skeletal measurements used in this study.*

* A table allowing such readings for the area over the triceps as well is unnecessary because of the high agreement between amount of subcutaneous tissue over the biceps and amount of subcutaneous tissue over the triceps, irrespective of all other factors.

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Summary of the Proposed Measures Intended to Approximate Nutritional Status

Material presented thus far has given consideration to five possible methods of estimating the degree to which the nourishment of a child is satisfactory. These five are:

A. Actual weight minus the weight to be expected from height.
B. Actual weight minus the weight to be expected from height, bisacromial width, chest dimensions, and width of hips.
C. Actual upper arm girth minus the upper arm girth to be expected from height, chest dimensions, and width of hips.
D. Actual calf girth minus the calf girth to be expected from height, chest dimensions, and width of hips.
E. Actual amount of subcutaneous tissue over the biceps minus the amount of subcutaneous tissue over the biceps to be expected from height, chest dimensions, width of hips, and bisacromial width.

The arguments which influence us to advise against any height-weight determination (A above) are as follows:

1. Individual differences in chest dimensions and hips are even more important than height as determinants of variations in weight. This leads us to the conclusion that children who are "underweight" on the height-weight tables are underweight mainly for other reasons than condition of muscle and subcutaneous tissue and yet it is these latter that we customarily associate with nutrition.
2. The correlation of height with girth of upper arm and girth of calf for constant values in other bony dimensions is practically zero, and height with amount of subcutaneous tissue for constant values in other bony dimensions is negative. When we expect more weight for tall children than for short ones (as we do by use of height-weight tables) we are penalizing tall children unduly in regard to the weight which is associated with girths.
3. The correlations of weight for a given height with girth residuals and with subcutaneous tissue residuals are low. If girth and subcutaneous tissue in terms of body build measure aspects of malnutrition then weight-height determinations are not measures of these same aspects. It seems impossible that weight for a given height should

to any large extent measure some aspect of nutritional status not apparent in condition of muscles and subcutaneous tissue. We therefore conclude that weight-height ratios measure mainly developmental factors not associated with nutrition. The low correlations which follow substantiate this conclusion.

Actual Weight Minus the Weight Expected from Height, Correlated with Actual Girths and Amount of Subcutaneous Tissue, Each Minus Expectations from Skeletal Components *

	Girls			Boys		
Age	10	11	12	10	11	12
Weight-Height Residuals with						
Arm Girth Residuals	.36	.32	.33	.42	.41	.37
Calf Girth Residuals	.31	.29	.28	.34	.37	.33
Amount of Subcutaneous Tissue over the Biceps Residuals	.19	.19	.18	.26	.27	.22

* Methods used are explained in Appendix C–6.

The arguments which eliminate actual weight minus weight to be expected from five skeletal dimensions (B above) are:

1. The multiple of skeletal dimensions with weight is too high to make the residuals seem important.
2. The elements of weight not predicted by skeletal dimensions are predicted by girths, therefore a direct consideration of girths would seem the preferable technique.
3. We may analytically account for all individual differences in weight except very small residuals which are easily attributed to differences in elimination, clothing and errors of recording. Weight is the combined result of many factors of growth and is highly ambiguous as a diagnostic measure.

The reasons given for emphasizing the use of the two girth residuals (C and D above) are:

1. All clinicians are strongly influenced in their judgments of nutritional status by individual differences in girth of upper arm and calf.
2. There is some evidence of a general tendency to be large or small muscled in relation to one's skeletal peers. It is further probable that the use of arm girth residuals and calf girth residuals together indicate the degree of muscle adequacy over the whole body.

3. Girth of upper arm and calf include a large proportion of that element of weight not represented by bony frame.
4. The multiple correlation of either arm girth or calf girth with five skeletal measures is considerably lower than that of weight with these same five measures. This makes the residuals large and more probable than weight residuals as physical signs of recent disturbances in the nutritional process.

Our reasons for recommending the use of actual amount of subcutaneous tissue over the biceps minus the amount of such tissue to be expected from five skeletal measures (E above) are:

1. It is the accepted opinion of the medical profession that amount of subcutaneous tissue is an element in nutritional status. Whenever a child is considered as totally satisfactory he is very sure to be called satisfactory in this quality also and vice versa (Table 3).
2. Nevertheless, amount of subcutaneous tissue does not play a part in their actual judgments. Children who are actually unsatisfactory in this quality as measured are as often as not called satisfactory totally (Table 5).
3. The multiple correlation of skeletal factors with this quality is between .5 and .6 which is low enough to insure very large residuals.
4. The subcutaneous tissue residuals have a low correlation with the girth residuals and therefore may be considered as valuable additions which do not in any way duplicate the girth residuals in significance.
5. Differences in amount of subcutaneous tissue over the biceps represent differences in amount of subcutaneous tissue in other portions of the body.*

* Our data, of course, merely show a high correlation between amount of subcutaneous tissue over the biceps with amount of subcutaneous tissue over the triceps for given skeletal composites. It is desirable at some future time to show that these two are themselves highly correlated with amount of subcutaneous tissue in other portions of the body. Our observations definitely lead us to believe this is true, especially since the correlation of these two with amount of subcutaneous tissue over the calf is as high as is reasonable in the light of the unobjectivity of this latter measure.

In this connection we may note that of these two there is a consistently greater amount of subcutaneous tissue over the triceps. This seems to indicate that our two measures on the upper arm are not measures of the same area of tissue.

Chapter IV

THE SYMMETRY OF GROWTH

THE high interrelations of various aspects of growth shown in our original tables imply a high degree of shared influence. But these anthropometric qualities do not overlap each other in influence in the same degree and kind. Some of our skeletal measurements bear a far greater affinity to weight and girth in their own right than do the others. Bisacromial width, for instance, has little influence on weight and girths which is not entirely represented by the other measurements as well, while hips is an important determinant of both of these qualities over and above such influences as it shares with chest dimensions and height. This is clearly shown in Charts I and II and in Tables 14 and 15. Height adds less than any other single skeletal factor to the adequacy of the predictions of that portion of weight which may be attributed to bony framework. This is shown in Charts III and IV. We may see in Table 15 that height has no contribution whatever to make in the predictions of that portion of calf girth due to bony development and actually contributes a subtraction rather than an addition to the predictions of arm girth as seen in Table 14. Thus our eleven characteristics are involved in a complicated interrelationship which suggests a balance of growth factors. *Such a balance stated in terms of formulæ should give an index of the symmetry of development.*

Expectation

We present in Chapter VI tables which allow a determination of how nearly the girths and the amounts of subcutaneous tissue of children conform to expectations justified by the skeletal dimensions of these children. These tables show the girth and amount of subcutane-

ous tissue appropriate to any body build, as defined by any possible combination of height, breadth of chest, depth of chest, width of hips, and bisacromial width. They give the average girth and the average amount of subcutaneous tissue for given conditions of age and skeletal conformity. These expectations which we have tabled may, of course, be stated as formulæ. All quantities in these formulæ are as described in Appendix A. As example, the following formula expresses the "Girth of Upper Arm Expectation" for eleven-year-old boys:

Upper Arm Girth (expected)*

$$= -.092 \text{ Ht.} + .433 \text{ Ch. Br.} + .632 \text{ Ch. D.} + .836 \text{ Hips} - 14.98$$

Use of this formula and use of Tables I and II in Chapter VI based upon it give the same results. The tables were made from this formula.

We may make like expectancy formulæ where our objective is to find the appropriate amount of any one of five skeletal dimensions for given values of the other four. These will yield for any child the amount of each of five skeletal qualities which is normally expected for his actual values in the other four. Thus for eleven-year-old girls we may predict the width of hips most likely for any combination of other skeletal attributes. The formula is:

Expectation of Hip Width

$$= .246 \text{ Ht.} + .166 \text{ Bisac.} + .134 \text{ Ch. Br.} + .201 \text{ Ch. D.} - 5.17$$

A particular eleven-year-old girl selected at random has the following measurements (quantities obtained as described in Appendix A):

Height	55.75
Bisacromial Width	29.5
Breadth of Chest	41.0
Depth of Chest	32.5

When these amounts are substituted in the formula given immediately above we get the following result:

$$13.71 + 4.90 + 5.49 + 6.53 - 5.17 = 25.46$$

* Relation of these coefficients to those in previous tables is discussed in Appendix C–3, 4.

This is the hip expectation of the particular girl chosen at random to illustrate the procedure. Her actual breadth of hips as measured was 25.3. Comparison of expectation with actual is our present objective.

Formulæ to be Used in the Calculation of Expectations

We desire to calculate all five skeletal expectations most probable for actual values in the other four for any child ten, eleven, or twelve years old of either sex. The thirty formulæ in Table X achieve these predictions.

Table X

EQUATIONS TO OBTAIN EXPECTATION OF EACH SKELETAL TRAIT BY AGE AND SEX GROUPS

Regression Equations to Predict Height

Ten-Year-Old Girls

Expectation of Height = .741 Bisac. — .031 Ch. Br. + .052 Ch. D. + .529 Hips + 19.26

Eleven-Year-Old Girls

Expectation of Height = .629 Bisac. — .024 Ch. Br. + .028 Ch. D. + .598 Hips + 21.84

Twelve-Year-Old Girls

Expectation of Height = .696 Bisac. — .133 Ch. Br. + .014 Ch. D. + .550 Hips + 26.44

Ten-Year-Old Boys

Expectation of Height = .674 Bisac. + .003 Ch. Br. + .104 Ch. D. + .507 Hips + 18.64

Eleven-Year-Old Boys

Expectation of Height = .458 Bisac. + .083 Ch. Br. + .000 Ch. D. + .615 Hips + 22.63

Twelve-Year-Old Boys

Expectation of Height = .692 Bisac. — .010 Ch. Br. + .006 Ch. D. + .592 Hips + 20.46

Regression Equations to Predict Bisacromial Width

Ten-Year-Old Girls

Expectation of Bisacromial Width
= .225 Ht. + .255 Ch. Br. — .068 Ch. D. + .179 Hips + 4.30

Eleven-Year-Old Girls

Expectation of Bisacromial Width
= .235 Ht. + .287 Ch. Br. — .063 Ch. D. + .150 Hips + 2.89

Table X

Continued

Twelve-Year-Old Girls

Expectation of Bisacromial Width
= .246 Ht. + .266 Ch. Br. — .065 Ch. D. + .188 Hips + 2.30

Ten-Year-Old Boys

Expectation of Bisacromial Width
= .219 Ht. + .292 Ch. Br. — .048 Ch. D. + .138 Hips + 3.54

Eleven-Year-Old Boys

Expectation of Bisacromial Width
= .229 Ht. + .213 Ch. Br. — .030 Ch. D. + .185 Hips + 4.60

Twelve-Year-Old Boys

Expectation of Bisacromial Width
= .216 Ht. + .256 Ch. Br. — .057 Ch. D. + .214 Hips + 3.75

Regression Equations to Predict Breadth of Chest

Ten-Year-Old Girls

Expectation of Breadth of Chest
= —.031 Ht. + .834 Bisac. + .371 Ch. D. + .243 Hips + 1.14

Eleven-Year-Old Girls

Expectation of Breadth of Chest
= —.024 Ht. + .772 Bisac. + .318 Ch. D. + .327 Hips + 2.29

Twelve-Year-Old Girls

Expectation of Breadth of Chest
= —.147 Ht. + .834 Bisac. + .340 Ch. D. + .435 Hips + 3.70

Ten-Year-Old Boys

Expectation of Breadth of Chest
= .003 Ht. + .844 Bisac. + .225 Ch. D. + .337 Hips + 1.79

Eleven-Year-Old Boys

Expectation of Breadth of Chest
= .094 Ht. + .483 Bisac. + .281 Ch. D. + .412 Hips + 4.27

Twelve-Year-Old Boys

Expectation of Breadth of Chest
= —.010 Ht. + .828 Bisac. + .273 Ch. D. + .343 Hips + 1.44

Regression Equations to Predict Depth of Chest

Ten-Year-Old Girls

Expectation of Depth of Chest = .059 Ht. — .258 Bisac. + .429 Ch. Br. + .658 Hips + .98

Eleven-Year-Old Girls

Expectation of Depth of Chest = .037 Ht. — .223 Bisac. + .421 Ch. Br. + .648 Hips + 1.74

Table X

Continued

Twelve-Year-Old Girls

Expectation of Depth of Chest = .025 Ht. — .322 Bisac. + .542 Ch. Br. + .517 Hips + 3.49

Ten-Year-Old Boys

Expectation of Depth of Chest = .122 Ht. — .175 Bisac. + .280 Ch. Br. + .507 Hips + 5.46

Eleven-Year-Old Boys

Expectation of Depth of Chest = .000 Ht. — .071 Bisac. + .292 Ch. Br. + .546 Hips + 7.57

Twelve-Year-Old Boys

Expectation of Depth of Chest = .008 Ht. — .235 Bisac. + .352 Ch. Br. + .745 Hips + 4.79

Regression Equations to Predict Width of Hips

Ten-Year-Old Girls

Expectation of Width of Hips = .196 Ht. + .218 Bisac. + .091 Ch. Br. + .213 Ch. D. — 2.66

Eleven-Year-Old Girls

Expectation of Width of Hips = .246 Ht. + .166 Bisac. + .134 Ch. Br. + .201 Ch. D. — 5.17

Twelve-Year-Old Girls

Expectation of Width of Hips = .258 Ht. + .251 Bisac. + .184 Ch. Br. + .138 Ch. D. — 8.34

Ten-Year-Old Boys

Expectation of Width of Hips = .195 Ht. + .163 Bisac. + .138 Ch. Br. + .166 Ch. D. — 1.98

Eleven-Year-Old Boys

Expectation of Width of Hips = .231 Ht. + .139 Bisac. + .137 Ch. Br. + .174 Ch. D. — 3.39

Twelve-Year-Old Boys

Expectation of Width of Hips = .195 Ht. + .227 Bisac. + .112 Ch. Br. + .189 Ch. D. — 3.45

Deviations of Actual from Expectation

In the example of an eleven-year-old girl selected at random and given above we found that this case "should" have a width of hips of 25.46. The actual width of hips of this child was 25.3. It may be seen that this child has a width of hips which is appropriate to her other dimensions. She does not deviate materially in width of hips from the amount of that dimension normal to other eleven-year-old girls who measure as she does in height, shoulders, and chest dimensions. A mathematical statement of this would be a subtraction of her "width of hips expectation" from the "actual width of hips as meas-

used" [25.3 − 25.46 = −.16]. We may call this remainder a "*residual.*" It is the amount to which a child differs in a given value from the dimension that she "ought" to have where "ought" means that value which is common to children like her in other skeletal dimensions.

We give immediately below the actual and expected width of hip measurements, together with the residuals, for two cases of each age-sex group, chosen at random:

Width of Hips

Case	Age	Sex	Actual	Expected	Residual
a	10	Girl	23.5	23.2	+0.3
b	10	Girl	28.4	27.2	+1.2
c	10	Boy	27.3	26.4	+0.9
d	10	Boy	24.0	24.1	—0.1
e	11	Girl	25.3	25.4	—0.1
f	11	Girl	24.8	23.8	+1.0
g	11	Boy	27.0	28.2	—1.2
h	11	Boy	26.0	25.9	+0.1
i	12	Girl	30.1	29.3	+0.8
j	12	Girl	24.4	27.4	—3.0
k	12	Boy	27.8	27.4	+0.4
l	12	Boy	25.9	26.3	—0.4

We need now a table which will allow the translation of these amounts into values necessary to show when a residual is important and when it is negligible. Inspection of the twelve cases above shows immediately that for Case j the width of hips is less than would be expected from her other bony dimensions by an amount that is considerably more than the discrepancy usual between actual and expected hip measures.

Comparability of Residuals

The necessity of an interpretation of the degree of importance attached to the amount of a residual is emphasized by consideration of the comparison of residuals of one kind with residuals of the same children of another kind. Being a given number of inches shorter than

is warranted by the other skeletal dimensions must be compared with having depth of chest a given number of centimeters less than is to be expected from the remaining body build. We can, of course, measure residuals of any given child in each of the five characteristics. These amounts of asymmetry need each to be divided by some factor that renders these measures comparable. Such a factor is the amount of dispersion in that particular aspect. The deviation in height from expectation and the deviation in hips from expectation must each be expressed in terms of their variability before they are comparable.*

We can make a table for any child which has in it the following facts:

1. Actual measure in each of the five characteristics.
2. Expectation in each of these five characteristics from the other four.
3. Actual minus expectation, which is the residual.
4. This residual divided by the standard deviation of the residuals of that kind.
5. The number of children in this age-sex group likely to be as atypical or more atypical than this one.†

Three such tables for three eleven-year-old girls are given below as illustrations:

Case No. 1

	Actual	Expected	Residual	Standard Score of Asymmetry	Approximate Per Cent of Children More Unusual
Height	55.8	55.5	+0.3	+0.18	86
Bisacromial Width	29.5	29.5	0.0	0.00	100
Breadth of Chest..	41.0	42.3	—1.3	—0.76	45
Depth of Chest....	32.5	30.9	+1.6	+0.80	42
Width of Hips....	25.3	25.5	—.02	—0.18	86

* Mathematically expressed, this means that we reduce each variable to $\frac{x}{\sigma_x}$. Since we deal here with residuals these standard scores are:

$$\frac{X_1 - [\beta_{12.34\ldots n}\frac{\sigma_1}{\sigma_2}(X_2 - M_2) + \beta_{13.24\ldots n}\frac{\sigma_1}{\sigma_3}(X_3 - M_3) + \ldots . \beta_{1n.23\ldots n-1}\frac{\sigma_1}{\sigma_n}(X_n - M_n) + M_1]}{\sigma_1\sqrt{1 - R_{1.23\ldots n}^2}}$$

† These values are obtained with the aid of Pearson's Tables by computing the number of cases beyond any absolute standard score value in a normal distribution area.

Case No. 2

	Actual	Expected	Residual	Standard Score of Asymmetry	Approximate Per Cent of Children More Unusual
Height	54.0	53.9	+0.1	+0.06	95
Bisacromial Width.	27.5	28.3	—0.8	—0.80	42
Breadth of Chest..	38.0	40.0	—2.0	—1.18	24
Depth of Chest....	30.3	29.7	+0.6	+0.30	76
Width of Hips....	24.8	23.8	+1.0	+0.91	36

Case No. 3

	Actual	Expected	Residual	Standard Score of Asymmetry	Approximate Per Cent of Children More Unusual
Height	56.0	55.8	+0.2	+0.12	90
Bisacromial Width.	29.9	30.0	—0.1	—0.10	92
Breadth of Chest...	42.4	42.9	—0.5	—0.29	77
Depth of Chest....	33.3	31.4	+1.9	+0.95	34
Width of Hips....	25.4	25.9	—0.5	—0.45	65

The residuals in column 3 represent the degree to which these three selected cases diverge from normal symmetry in each of the characteristics. Case 1 is smaller in breadth of chest and larger in depth of chest than is usual for children of her age and her other dimensions. Case 2 also diverges negatively in breadth of chest from the expectation and, in addition, has a width of hips a little larger than is normal for her age. All three cases are very slightly taller than the average of eleven-year-old girls like them in other ways. But column 4 is necessary to give these residuals practical value. There are two very important reasons why they must be translated into other terms. In the first place we do not know how important it is to be .1 of an inch, .2 of an inch, or .5 of an inch taller than are others of the same age, chest dimensions, and hips. Otherwise stated, a centimeter of divergence from expectation in hips is by no means of equal biological importance with a centimeter of divergence in depth of

chest. We must find a common denominator for these residuals in order to evaluate, compare, and combine them. In order to do this we express them as multiples of their variability. In the second place, we may only give the importance of any one residual by translation into the percentage of a large number of individuals who have a residual as great, or as small, as the particular obtained value. Then we have given its biological significance. When residuals are expressed as multiples of their variability then they have a common denominator in a true biological sense and they may also be translated into ranks representative of the frequency of their occurrence. Column 4 in our illustrative cases expresses these standard scores of asymmetry. Column 5 expresses the severity of any given standard score of asymmetry. The greater the number of children who are more unusual than a given case, the more symmetrical is this case.

Table Y immediately following gives the standard deviation of the residuals for each of the formulæ stated in Table X. Using actual measurements minus the appropriate residuals obtained from Table X as the numerators and using the quantities tabled in Y as the denominators, the resultant quotients will give standard scores of asymmetry. These quotients read into Table Z give the number of children out of a representative 100 more atypical than the one under observation. The table gives these amounts whether the quotients are positive or negative.

Table Y

STANDARD DEVIATIONS OF RESIDUALS *

	Height	Bisacromial Width	Breadth of Chest	Depth of Chest	Width of Hips
Girls, Ten Years Old	1.6	.9	1.6	1.7	1.0
Eleven Years Old	1.7	1.0	1.7	2.0	1.1
Twelve Years Old	1.7	1.0	1.8	2.2	1.1
Boys, Ten Years Old	1.6	.9	1.5	1.7	1.0
Eleven Years Old	1.7	1.2	1.8	1.8	1.0
Twelve Years Old	1.8	1.0	1.8	2.0	1.0

* This is the standard error of estimate in the multiple correlation involved.

Table Z

PER CENT OF CHILDREN WHO ARE MORE ATYPICAL THAN A CHILD WITH A GIVEN STANDARD SCORE OF ASYMMETRY *

Standard Score	Approximate Per Cent of Children More Unusual	Standard Score	Approximate Per Cent of Children More Unusual	Standard Score	Approximate Per Cent of Children More Unusual
2.58	1	0.93	35	0.40	69
2.33	2	0.92	36	0.39	70
2.17	3	0.90	37	0.37	71
2.05	4	0.88	38	0.36	72
1.96	5	0.86	39	0.35	73
1.88	6	0.84	40	0.33	74
1.81	7	0.82	41	0.32	75
1.75	8	0.81	42	0.31	76
1.70	9	0.79	43	0.29	77
1.64	10	0.77	44	0.28	78
1.60	11	0.76	45	0.27	79
1.55	12	0.74	46	0.25	80
1.51	13	0.72	47	0.24	81
1.48	14	0.71	48	0.23	82
1.44	15	0.69	49	0.21	83
1.41	16	0.67	50	0.20	84
1.37	17	0.66	51	0.19	85
1.34	18	0.64	52	0.18	86
1.31	19	0.63	53	0.16	87
1.28	20	0.61	54	0.15	88
1.25	21	0.60	55	0.14	89
1.23	22	0.58	56	0.13	90
1.20	23	0.57	57	0.11	91
1.18	24	0.55	58	0.10	92
1.15	25	0.54	59	0.09	93
1.13	26	0.52	60	0.08	94
1.10	27	0.51	61	0.06	95
1.08	28	0.50	62	0.05	96
1.06	29	0.48	63	0.04	97
1.04	30	0.47	64	0.03	98
1.02	31	0.45	65	0.01	99
0.99	32	0.44	66	0.00	100
0.97	33	0.43	67		
0.95	34	0.41	68		

* Table Z is computed from Table II, Pearson's Tables for Statisticians and Biometricians.

Research Applications

These scores express asymmetry in terms of its biologic occurrence. As such, they are indices of development which have important possibilities as predictions which may prove valuable to health. They are useful in the understanding of development and its discrepancies. Thus abnormality in breadth of hips is now defined in terms of biologic deviation from what is normal according to the remaining elements of structure. When such abnormality as this is detected we are laying our fingers upon functions related to growth. We are bringing clearly into relief the unusual in bodily development.

We have here also methods of measurement which are very likely to prove important aids in the prevention of disease. Depth of chest, for instance, which is markedly less than might normally be expected from the height and breadth of a child may be found to be an indication of susceptibility to diseases whose occurrence may be prevented by extraordinary care under medical supervision. Any of these physical dimensions which do not correspond in amount to what is appropriate for the remaining elements of structure should be carefully recorded, in order that observations in the future may show the relation of such discrepancy to subsequent morbidity and mortality. It is also possible that the biological discrepancies determined by these methods may be found to have an important bearing upon the prognosis of some diseases.

Types of prescribed exercise and favorable athletic media do certainly depend in part on body build. Thus these measures should, with experiment, improve the adaptation of physical education to individual needs. We may even hope to predict those forms of athletic competition in which the individual will find interest and success as well as suitable activity. The degrees of normality with which we here deal certainly must bear some relation to athletic prowess and athletic needs.

Economy of Nutrition

The usefulness of this procedure may be enhanced by predictions which involve other characteristics as well as the skeletal dimensions. Data which allow the determination of expectation and standard residuals, in terms of the eight important selected measures, are included in Appendix D. The reader may find there the β's, multiple R's and σ's necessary for such calculations. By the aid of these formulæ he may find how serious is any child's discrepancy in any of eight characteristics from the expectation justified by the other seven.

These formulæ, however, are hard to interpret because the distinctions between traits are not always sharply defined. Girth of upper arm, for instance, has, as we have shown, much in common with girth of calf and so in the expectations of this latter characteristic, figured from factors inclusive of the former, we get closer to what it really is than we wish to do. We would much rather know instead what girth of calf is justified by physical qualities not including muscle size of any kind, so that our residuals would be larger and more significant. The same is true in regard to the two measures of amount of subcutaneous tissue. So, too, the bony measurements used amongst themselves give a measure of structural symmetry, but are too closely interrelated to be used in conjunction with other qualities in kind like muscle size as terms in the prediction of any one skeletal component.

For this reason, we have combined terms in order to gain three qualities: (1) "Muscle Size" as represented by girth of upper arm and girth of calf weighted in inverse ratio to their standard deviations; * (2) "Amount of Subcutaneous Tissue" as represented by the caliper measures of this quality over the biceps and triceps weighted inversely as their standard deviations; and (3) "Body Build" as represented by height, the two chest dimensions, and breadth of hips weighted inversely as their standard deviations.

* Such weighting results in equal emphasis for the component parts.

Using basic quantities as described in Appendix A these composites are found as follows:

Muscle Size = arm girth + 2 (calf girth)
Amount of
Subcutaneous Tissue = amount over biceps + 3 (amount over triceps)
Body Build = height + chest breadth + chest depth + 1.5 (hips)

These three qualities are intercorrelated as follows:

Age and Sex	Number	Muscle Size with Body Build (Zero order r)	Body Build with Muscle Size Plus Subcutaneous Tissue (Multiple R)	Muscle Size with Body Build Plus Subcutaneous Tissue (Multiple R)
Girls 10	909	.81	.81	.84
11	1000	.83	.83	.86
12	500	.87	.87	.89
Boys 10	788	.84	.84	.87
11	1000	.80	.80	.85
12	600	.85	.85	.87
All Groups	4797	.83	.83	.86

Comparison of the zero order correlations in column 1 of this table with the multiples in columns 2 and 3 shows that our measure of amount of subcutaneous tissue adds nothing to the accuracy of body build predictions and contributes very little to the multiple relation of itself plus body build with muscle size. This leads us to conclude that we gain no new value by a computation of elements in the balance of these three large qualities. Girth expectations from skeletal components as described in Chapter III covers the considerations here involved. A comparison of the zero order correlations and the multiple correlation of subcutaneous tissue with the other two variables emphasizes this conclusion.

Age and Sex	Number	Amount of Subcutaneous Tissue with Body Build (Zero order r)	Amount of Subcutaneous Tissue with Muscle Size (Zero order r)	Amount of Subcutaneous Tissue with Body Build Plus Muscle Size (Multiple R)
Girls 10	909	.49	.59	.59
11	1000	.47	.60	.60
12	500	.51	.60	.60
Boys 10	788	.53	.63	.63
11	1000	.55	.69	.69
12	600	.53	.63	.63
All Groups	4797	.47	.59	.59

We see again that the subcutaneous tissue amount is predicted as well by muscle size alone as by muscle size and body build together. The correlation of body build with the subcutaneous tissue measure is due entirely to their common relation with muscle size.

We know from this that use of the subcutaneous tissue residuals advised in the previous chapter means a use of true measures of this quality independent of its relation to the girth measures. This is why the correlation of the two types of residuals is so low.

Summary

1. Measures of skeletal symmetry are derived.
2. The balance of three important elements of nutrition (muscle size, amount of subcutaneous tissue, and body build) reduces to a relation between muscle size and body build.
3. Amount of subcutaneous tissue apart from its relation to muscle size is entirely uncorrelated with body build.

Chapter V

AGE AND SEX DIFFERENCES

UP to this point in our discussions we have treated separately each of six age-sex groups. A consideration of the differences which occur in our selected anthropometric qualities because of age and sex are important for both theoretic and practical reasons. The theoretic reasons are associated with problems of growth and with the influence of the endocrines upon development. The practical reason is the need of decisions regarding the least number of tables that will allow adequate conclusions.

Comparisons are here made of twelve age-sex groups comprised of children between the ages of seven and twelve inclusive.* The children in the ten-, eleven-, and twelve-year age groups are those treated in previous chapters of this pamphlet. There are 500 of each age-sex group in the additional material considered here.

We may compare these twelve groups in respect to average and variability in each important quality. We may, in addition, compare the six groups which comprise our basic data in respect to the regression equations and multiple correlations previously developed. When we compare the average height of successive age groups we are viewing growth in height. When we compare the variability of successive age groups in regard to any quality we are comparing the extent of individual differences at successive periods of age. We may also compare the sexes in each age for each significant anthropometric quality in respect to average and variability.

* Throughout this chapter age 7 means 7½, age 8 means 8½, etc. Therefore, progress computed by comparison of the 7 year and 8 year groups means progress from a mean age of 7½ to a mean age of 8½, etc.

Maturation

The method used to make the age comparisons must reduce the increases for any given age interval to comparable units of amount. We wish to compare any given increase in height with increases of height in other age intervals and with other characteristics as well. In order to achieve this we must express age increases in terms of some true biologic unit. Biologic studies cannot rely upon the same relativities used in physical and chemical research. An inch is not always an inch in biologic discussions. An inch of increase, for instance, in breadth of shoulders is much more shoulder development than is an inch of increase in height development. We may choose the variability of some one age group as the basis of our relativity. We are then founding our comparisons upon the assumption that the root-mean-square deviation of eleven-year-olds in any given trait is biologically equal to the root-mean-square deviation of any other trait in this same age group.* We use root-mean-square deviation because it is the best mathematical measure of variability.

If one were asked whether a given improvement in high jumping was greater than another given improvement in broad jumping it would, of course, be absurd to compare them directly. An inch of high jumping and an inch of broad jumping are two very different biologic amounts even though they are both expressed in terms of inches. We may, however, achieve our comparison if we divide each by the root-mean-square deviation appropriate to it since then we are expressing each of the improvements as proportions of the variability which expresses its biologic variance. Similarly, we may compare growth in height with hip development, increases in calf girth, or development in chest dimensions, provided that each of these increases over time is divided by the amount of variability which the trait has in a group of unselected eleven-year-olds. Variability in each

* We are using eleven-year-olds because we have most cases in this group, and because it is the middle age group of the three upon which our major premises are founded. Use of any other age group would give us the same results. We are, of course, using the boy variability for age differences in boys and the girl variability for the age differences in girls.

of these traits is a biologic fact and if we express improvement in each trait as a proportion of this variation we gain a true comparability.

Table 22 gives the increases in ten age-sex intervals for each of eight important qualities. All amounts in this table are directly comparable as explained above. Low amounts in this table mean that the differences between averages of the groups considered are insignificant in comparison to the individual differences within a group and high amounts mean that average age differences in this quality are very large relative to the individual differences within an age group.

Table 22

GROWTH IN EACH OF EIGHT TRAITS FOR GIRLS AND FOR BOYS EXPRESSED IN COMPARABLE BIOLOGIC UNITS *

Age		Height	Width of Hips	Bis-acromial Width	Breadth of Chest	Depth of Chest	Girth of Calf	Girth of Upper Arm	Amount of Subcutaneous Tissue over Biceps
7½ to 8½	G.....	.70	.45	.52	.38	.21	.34	.30	.17
	B.....	.80	.40	.52	.42	.29	.42	.39	—.04
8½ to 9½	G.....	.75	.46	.53	.28	.16	.36	.29	.26
	B.....	.91	.51	.61	.35	.21	.48	.32	.23
9½ to 10½	G.....	1.01	.52	.75	.31	.18	.53	.38	.05
	B.....	1.00	.42	.84	.36	.18	.50	.39	.04
10½ to 11½	G.....	.63	.51	.45	.46	.39	.33	.27	.07
	B.....	.45	.29	.33	.43	.28	.31	.27	.00
11½ to 12½	G.....	.51	.61	.48	.42	.34	.27	.25	—.26
	B.....	.67	.56	.57	.46	.48	.41	.35	—.01

* Mean of the lower age was subtracted from mean of the upper age and the difference was divided by the eleven-year-old sigma.

We may see from this table that at the age interval 9½ to 10½ there are more instances of large increment in the various qualities of growth than at the other age intervals. Height and shoulders develop especially rapidly between 9½ and 10½ for both sexes. Girths also grow more rapidly in this period but the comparison to the other periods is not as marked as is the case with height and shoulders. The only quality which shows a decrease in any age interval is the one represented by our measure of amount of subcutaneous tissue

over the biceps. A marked increase in this quality is present only in the eighth year for boys and the seventh and eighth year for girls. There is a marked decrease in the eleventh year for girls.

Table 23

SEX DIFFERENCES IN RATE OF GROWTH *

Girl superiority underlined. "x" signifies no difference.

Age	Height	Width of Hips	Bisacromial Width	Breadth of Chest	Depth of Chest	Girth of Calf	Girth of Upper Arm	Amount of Subcutaneous Tissue over Biceps
7½ to 8½..	.10	.05	x	.04	.08	.08	.09	.21
8½ to 9½..	.16	.05	.08	.07	.05	.12	.03	.03
9½ to 10½..	.01	.10	.09	.05	x	.03	.01	.01
10½ to 11½..	.18	.22	.12	.03	.11	.02	x	.07
11½ to 12½..	.16	.05	.09	.04	.14	.14	.10	.25

* This is the sex difference of standard age differences.

The sex differences in the rate of maturation are very clearly displayed in Table 23. Between 7½ and 8½ the boys increase a little more than the girls in five of the eight qualities. Between 8½ and 9½ the boys increase more than the girls in all but one of the qualities but the amount of difference is still small. Between 9½ and 10½ superiority in increase is about equally divided with very small and unimportant differences. In the next year there is a marked sex change in rate of growth. The girls increase more than the boys in all traits (except for arm girth, which is the same) and in some qualities to a very emphatic degree. Between 11½ and 12½ the boys again show the greater increase in everything but hips. The differences in amounts are usually large and significant. It is very obvious that the development of the boys lags behind that of the girls between 10½ and 12½ years of age.

Table 24 gives the increases and decreases in amount of individual differences of each of the traits again expressed in terms of eleven-year-old dispersion. Variability increases more in all the other years studied than it does in the interval 8½ to 9½. In that

year there are many decreases in variability and, except in the case of bisacromial width in girls, such increases as appear are small. Marked increases come between the ages of 10½ and 11½ for girls and between 11½ and 12½ for boys. The male lag in development shown for rate of growth in Table 23 is shown here also in the increase of variability. A random group of girls become more different one from another between 10½ and 11½ than in any other year, whereas boys develop individual differences more between 11½ and 12½ than they do at other ages.

Table 24

AGE INCREASES AND DECREASES IN VARIABILITY EXPRESSED IN COMPARABLE BIOLOGIC UNITS *

Age		Height	Width of Hips	Bisacromial Width	Breadth of Chest	Depth of Chest	Girth of Calf	Girth of Upper Arm	Amount of Subcutaneous Tissue over Biceps
7½ to 8½	G	.07	.08	.09	.09	.10	.10	.15	.18
	B	x	.09	.08	.09	.06	.08	.12	.02
8½ to 9½	G	.05	.03	.10	x	x	.03	.02	x
	B	.04	—.03	—.04	.01	—.05	—.04	—.05	.03
9½ to 10½	G	—.02	.10	—.05	.14	.16	.04	.08	—.09
	B	.01	.10	.03	.10	.14	.08	.15	.02
10½ to 11½	G	.11	.17	.17	.12	.13	.17	.11	.03
	B	.04	.07	.11	.07	.07	.07	.06	.03
11½ to 12½	G	—.04	.10	.03	.11	.11	.03	.03	—.05
	B	.14	.12	.05	.15	.21	.14	.14	.01

* Sigma of the lower age was subtracted from sigma of the upper age and the difference was divided by the eleven-year-old sigma. Decreases are expressed as negative amounts. No increase or decrease is signified by "x."

Comparison of Growth in Various Traits

Comparison of growth in any one quality with any other for any year may be made by consulting Table 22. The relative importance of the qualities measured in our basic groups (ages 10½ to 12½) is of interest in relation to the regression equations which we have developed, since it may throw some light upon age differences in the prediction of any one trait from the others. It is also of some theoretic interest to answer such questions as, "In which of these

qualities do children grow the most and in which do they grow the least?" The validity of these comparisons, of course, rests entirely upon the relativity used. When we say here that children of these ages grow more rapidly in one trait than another we mean that differences existing between the average of ten-year-olds and the average of twelve-year-olds are a greater proportion of the trait's variability in one case than in the other. The facts below show that height, hips, and shoulders grow the most in these ages and that the girths grow the least. It is very significant to note that except for width of hips the order of growth importance is the same in boys as in girls.

Growth Indices

Twelve-year-old averages minus ten-year-old averages expressed in comparable units *

	Girls	Boys
Height	1.14	1.12
Width of Hips	1.12	.85
Bisacromial Width	.93	.90
Breadth of Chest	.88	.89
Depth of Chest	.73	.76
Calf Girth	.60	.72
Arm Girth	.52	.62
Amount of Subcutaneous Tissue over the Biceps	—.19	—.01

Sex Differences in Average Dimension at Each Age Level

The method used to compute the sex differences at each of the age levels was to determine a measure which is a function of the probability that the sex groups are really distinct.† These amounts are high when they are over 1.5 since this means that the chances are more than 93 out of 100 that the sex differences are in the direction indicated. When the amounts are 2.5 or over the chances are more than 99 out of 100 that sex differences exist as described,

* $(M_{12yr} - M_{10yr})$ divided by the sigma of eleven-year-olds.

† $(M_g - M_b) \div \sqrt{\frac{\sigma_g^2}{n_g} + \frac{\sigma_b^2}{n_b}}$ is the standard score of the difference of the averages.

Table 25

STANDARD SCORES SHOWING PROBABILITY OF SEX DIFFERENCES IN AVERAGE

	Height		Bisacromial Width		Breadth of Chest		Depth of Chest		Width of Hips		Girth of Upper Arm		Girth of Calf		Amount of Subcutaneous Tissue over Biceps	
Age	Boys Greater	Girls Greater	Boys Greater	Girls Greater	Boys Greater	Girls Greater	Boys Greater	Girls Greater	Boys Greater	Girls Greater	Boys Greater	Girls Greater	Boys Greater	Girls Greater	Boys Greater	Girls Greater
7..	2.2		3.6		7.3		5.4		.3		0.0	0.0		2.3		9.0
8..	2.1		2.3		6.1		5.2			1.0	.8			2.1		11.4
9..	2.8		2.7		6.4		5.5			.3	.5			1.2		12.1
10..	.5		3.4		7.1		5.0			3.2		.5		4.6		16.7
11..		5.3		.3	4.6		.5			7.9		1.4		6.0		19.4
12..		2.5	.5		2.4		.8			7.9	0.0	0.0		3.1		10.2

Table 26

STANDARD SCORES SHOWING PROBABILITY OF SEX DIFFERENCES IN VARIABILITY

	Height		Bisacromial Width		Breadth of Chest		Depth of Chest		Width of Hips		Girth of Upper Arm		Girth of Calf		Amount of Subcutaneous Tissue over Biceps	
Age	Boys Greater	Girls Greater	Boys Greater	Girls Greater	Boys Greater	Girls Greater	Boys Greater	Girls Greater	Boys Greater	Girls Greater	Boys Greater	Girls Greater	Boys Greater	Girls Greater	Boys Greater	Girls Greater
7..	.3		1.3		1.4		0.0	0.0	.4		.8		.1		1.4	
8..		1.5	.9		1.6			1.5	.7		2.1			.8	5.2	
9..		2.0		2.6	1.3			3.1	2.5		4.0			2.7	4.4	
10..		1.9		1.0	3.4			5.1	3.3		2.7			2.1	2.7	
11..		4.3		3.2	5.5			7.6	7.6		4.6			6.3	2.9	
12..	.7			1.9	3.0			3.7	4.8		1.0			1.9	.8	

and when the amounts are over 3 we may, of course, be absolutely certain of our conclusions.

Table 25 gives clear indication that height and bisacromial width show sex differences favorable to boys from seven to ten inclusive with the reservation that the sex differences in height for the ten-year-olds is small and unimportant. Boys exceed girls in all age groups studied in breadth of chest and in depth of chest though the differences for depth of chest in the eleven- and twelve-year-old groups are small enough to be uncertain. Girls in all age groups definitely and conclusively exceed the boys in girth of calf and in amount of subcutaneous tissue over the biceps. They also exceed the boys in width of hips in the ages eight to twelve and in this respect increase the amount and certainty of the distinction with each year of age. The figures for arm girth are inconclusive. We believe that a tendency toward the development of the biceps in the boys and a general growth of muscle at a faster rate in girls, as illustrated by the calf girth findings, tend in part to balance each other and so indicate no sex differences in this respect. However it should be noted that for sex groups having equal amounts of subcutaneous tissue the boys show larger upper arm girths than do the girls.

The quantities in Table 26 should be interpreted as are those in Table 25. Practically all the sex differences in variability are in favor of girls. These differences increase in size and importance as age increases and all reach certainty in the eleven-year-old comparisons. It is of considerable biological importance that in respect to these characteristics the female is more variable than the male.

Age and Sex Differences in Multiple Correlations

We present in Table 27 all the multiple correlations computed from combinations of skeletal measures. The main conclusions from Table 27 are that there is a small but evident increase in multiple correlations associated with an increase in age. There is also a very definite tendency for multiple correlations to be higher in the case

of girls than they are for boys. This is probably due to the higher variability of girls in the traits which are involved.

Table 27

MULTIPLE CORRELATIONS OF SKELETAL MEASURES WITH VARIOUS ANTHROPOMETRIC QUALITIES FOR SIX SEX-AGE GROUPS *

	Girls			Boys		
Age	10	11	12	10	11	12
Number of Cases	909	1000	500	788	1000	600
Weight	.93	.95	.95	.92	.92	.93
Arm Girth	.81	.85	.86	.80	.81	.85
Calf Girth	.79	.82	.85	.76	.78	.83
Amount of Subcutaneous Tissue over the Biceps	.56	.55	.53	.59	.61	.61
Amount of Subcutaneous Tissue over the Triceps	.55	.54	.52	.56	.56	.57
Height	.76	.79	.78	.74	.71	.76
Bisacromial Width	.81	.83	.85	.80	.70 †	.83
Breadth of Chest	.81	.83	.86	.79	.73	.81
Depth of Chest	.74	.75	.74	.62	.61	.69
Width of Hips	.81	.84	.86	.76	.77	.83

* These R's are always the variable in the column at the left with all five skeletal measures except when this variable is itself one of the five. Then the multiple is with the other four.

† We have discovered errors in recording of bisacromial width at the time of measurement which account for this discrepancy.

Age and Sex Differences in Regression Equations

The multiple regression equations in previous chapters were derived separately for each age-sex group. Their objective is, of course, the determination of "expectation" in any one quality normal to any possible grouping of the others involved in the equation. If the equation which gives the best prediction of any quality for one age-sex group is very much like the equation which gives the best prediction in another age-sex group it may be possible to use one equation only for both groups in the calculation of "expectation" in this trait. This would also have theoretic importance because if the ten-year-old equation may be used with twelve-year-olds as well as the twelve-year-old equation and vice versa, it means that when a ten-year-old child is like a twelve-year-old in four out of five of the

skeletal traits he is like the twelve-year-old in the fifth one also. It also means that if a twelve-year-old is like a ten-year-old in four of the five qualities that he is like the ten-year-old in the fifth one also. We have seen that there are age and sex differences. These age and sex differences tend however to occur in such a manner as to suggest that one regression equation may fit all three ages of a sex or both sexes of an age or possibly all six age-sex groups.

The method chosen to determine the degree to which a regression equation for predicting a given trait in one group will fit for predicting that trait in another group was as follows: The mean values of the second group are substituted in the regression equation of the first.* The difference between the actual mean of the trait for the second group and the "expectation" obtained as described constitutes the degree to which the regression equations for the two groups are different in the values calculated from them. (The reason that we cannot compare the regression equations by comparing the coefficients of standard score is because they are often compensatory in their effect.)

Differences arrived at in this way are divided by the appropriate error of estimate. The differences are then translated into the proportion which they constitute of the spread around the regression line. When this quotient is under .5 the amount of error due to the use of the wrong regression is negligible. Table 28 gives these amounts irrespective of sign.† The regressions considered are the same ones described by multiples in Table 27.

We may see from Table 28 that there is no conclusive evidence of either age or sex differences in regression predictions of bisacromial width, chest depth, arm girth, or calf girth. There is a very slight tendency to indicate that there are age differences in regression in regard to height predictions but no sex differences. There are sex differences in the regression equations predicting hips and chest

* If the means of the second group are put into the regression equation of the second group, then of course, the "expectation" that is computed is exactly equal to the actual mean of this trait for that particular group.

† The mathematical index carries a complete consideration of the assumptions underlying this method and a mathematical statement of the formulae used. Appendix C–8.

Table 28

AGE AND SEX DIFFERENCES IN REGRESSION

True mean of a group minus the mean of the group as predicted by regression equation of a second group, divided by standard error of estimate, irrespective of sign

Age Differences of Girls

Age Group of which Regression Equation Was Used	Age Group of which Averages Were Used	Height	Width of Hips	Bisacromial Width	Breadth of Chest	Depth of Chest	Girth of Calf	Girth of Upper Arm	Amount of Subcutaneous Tissue over Biceps
10	11	.35	.14	.03	.07	.02	.14	.23	.21
10	12	.45	.56	.06	.03	.14	.42	.56	.87
11	10	.36	.04	.07	.07	.00	.14	.21	.15
11	12	.07	.32	.06	.04	.10	.27	.28	.57
12	10	.63	.18	.07	.03	.01	.48	.46	.76
12	11	.16	.23	.03	.06	.04	.30	.26	.58

Age Differences of Boys

Age Group of which Regression Equation Was Used	Age Group of which Averages Were Used	Height	Width of Hips	Bisacromial Width	Breadth of Chest	Depth of Chest	Girth of Calf	Girth of Upper Arm	Amount of Subcutaneous Tissue over Biceps
10	11	.21	.07	.08	.21	.02	.04	.11	.29
10	12	.46	.15	.12	.09	.15	.12	.26	.67
11	10	.21	.03	.03	.18	.00	.05	.11	.29
11	12	.31	.03	.17	.06	.18	.09	.18	.38
12	10	.44	.06	.10	.06	.06	.19	.24	.50
12	11	.24	.02	.18	.11	.11	.12	.15	.29

Sex Differences

Age-Sex Group of which Regression Equation Was Used	Age-Sex Group of which Averages Were Used	Height	Width of Hips	Bisacromial Width	Breadth of Chest	Depth of Chest	Girth of Calf	Girth of Upper Arm	Amount of Subcutaneous Tissue over Biceps
10 G	10 B	.01	.53	.12	.32	.24	.46	.23	1.00
10 B	10 G	.04	.54	.06	.41	.29	.52	.28	1.13
11 G	11 B	.11	.54	.05	.47	.13	.30	.07	1.01
11 B	11 G	.15	.58	.09	.51	.13	.31	.03	1.13
12 G	12 B	.10	.87	.22	.43	.19	.08	.14	.66
12 B	12 G	.08	.98	.24	.41	.38	.07	.27	.63

breadth but no evidence whatever of age differences. There are age and sex differences apparent in the predictions of amount of subcutaneous tissue over the biceps.

Summary

1. Development between 9½ and 10½ is greater than in any other year between 7½ and 12½.
2. The male lag in development comes between 10½ and 12½ in all characteristics.
3. There is general increase in variability in all years except age 8½ to 9½.
4. The male lag in increase of variability is between 10½ and 12½. It is very marked.
5. Height develops faster than any other traits between 10½ and 12½, whereas the girths develop most slowly. Amount of subcutaneous tissue does not increase at all in this period.
6. Boys exceed girls in chest dimensions in all age groups between 7 and 12 inclusive. Girls exceed boys in width of hips, girth of calf, and amount of subcutaneous tissue in these age groups. In height and shoulders boys exceed girls below 10 and girls exceed boys at 11.
7. With a few minor exceptions the female is more variable than the male in the traits measured between 7½ and 12½ inclusive.
8. Multiple correlations between skeletal combinations and any one quality are higher in girls than in boys and increase with age.
9. Appreciable differences in regression due to age occur only in height and amount of subcutaneous tissue.
10. Significant differences in regression due to sex occur only in hips, chest breadth and amount of subcutaneous tissue.
11. Regression formulæ for sex groups irrespective of age were computed for the symmetry equations presented in Chapter IV.

Supplement to Table X

EQUATIONS TO OBTAIN EXPECTATIONS IRRESPECTIVE OF AGE

Regression Equations to Predict Bisacromial

Ten, Eleven, Twelve-Year-Old Girls

Expectation of Bisacromial = .231 Ht. + .271 Ch. Br. — .066 Ch. D. + .174 Hips + 3.35

Ten, Eleven, Twelve-Year-Old Boys

Expectation of Bisacromial = .229 Ht. + .248 Ch. Br. — .041 Ch. D. + .181 Hips + 3.58

Regression Equations to Predict Chest Breadth

Ten, Eleven, Twelve-Year-Old Girls

Expectation of Chest Breadth = —.049 Ht. + .806 Bisac. + .342 Ch. D. + .327 Hips + 1.83

Ten, Eleven, Twelve-Year-Old Boys

Expectation of Chest Breadth = .051 Ht. + .659 Bisac. + .265 Ch. D. + .388 Hips + 2.33

Regression Equations to Predict Chest Depth

Ten, Eleven, Twelve-Year-Old Girls

Expectation of Chest Depth = .039Ht. — .260 Bisac. + .453 Ch. Br. + .612 Hips + 2.24

Ten, Eleven, Twelve-Year-Old Boys

Expectation of Chest Depth = .044 Ht. — .125 Bisac. + .305 Ch. Br. + .592 Hips + 5.14

Regression Equations to Predict Hips

Ten, Eleven, Twelve-Year-Old Girls

Expectation of Hips = .243 Ht. + .213 Bisac. + .135 Ch. Br. + .190 Ch. D. — 6.12

Ten, Eleven, Twelve-Year-Old Boys

Expectation of Hips = .215 Ht. + .166 Bisac. + .133 Ch. Br. + .177 Ch. D. — 3.27

Supplement to Table Y

STANDARD DEVIATIONS OF RESIDUALS IRRESPECTIVE OF AGE *

	10-, 11-, 12-Year-Old Girls	Boys
Bisacromial	1.0	1.1
Chest Breadth	1.7	1.7
Chest Depth	2.0	1.9
Hips	1.1	1.0

* When Supplement to Table X is used values in this table should be used as divisors for determining standard score of asymmetry to be read into Table Z.

Chapter VI

DETERMINATION OF THE RESIDUALS FOR ARM GIRTH, CALF GIRTH, AND BICEPS SUBCUTANEOUS TISSUE *

THE application to school conditions of conclusions reached in previous chapters should await criticism from specialists in anthropometry and the clinical aspects of nutritional status. If our proposals properly modified are acceptable, devices may be constructed which will allow for a simplified technique applicable to school conditions. Adaptations of the apparatus may lead to direct reading of girth expectations from the calipers used to determine skeletal dimension. Abbreviated tables may be constructed using only the most essential measurements.

While awaiting the verdict of a competent jury it may be of service to comprehension and to research applications to present the method of measurement in its present form. We realize that the methods as here presented are too involved to allow widespread school use. We feel, however, that these methods can be applied to some situations where intensive evaluations are desired.

The measurements necessary to determine the arm girth, calf girth, and biceps subcutaneous tissue residuals for any given child are: (1) Height, (2) width of hips, (3) chest depth, (4) chest breadth, (5) bisacromial width, (6) arm girth, (7) calf girth, (8) amount of subcutaneous tissue over biceps. These measurements should be taken in the manner described in Appendix A. Once these measurements have been made, the average girth and subcutaneous tissue to be expected for any skeletal arrangement can be deter-

* This chapter is the detailed routine of determining arm girth, calf girth, and biceps subcutaneous tissue residuals. Readers not interested in the method of obtaining these residuals may omit reading this chapter.

mined by a substitution in formulæ such as those given in Appendix B, Table I. To facilitate the calculation of this average or expected girth, each girth formula has been divided into two parts and tables constructed for the calculation of each part. Then by an addition of these two table readings the expected girth can be ascertained. We present here the tables for eleven-year-old boys as an illustration.* Tables I and II are used for determining the expected arm girth; Tables III and IV give the expected calf girth; Tables V, VI, and VII give the expected subcutaneous tissue over the biceps. Tables VIII, IX, and X allow interpretations of the residuals of arm girth, calf girth, and subcutaneous tissue respectively.

Table I is a two-way table giving partial values for any skeletal combination of height and hips. Table readings are given for height intervals of one inch. The height given at the top of the table is the lower limit of the interval; for example, the column headed 54 should be used for all children whose height ranges between 54 inches and 55 inches. Similarly table readings are given for .25 centimeter intervals for the hips and again the lower limit of the interval is the one given on the table. These hip intervals are shown at the extreme left of the table. After every fourth column the hip measures are repeated for ease of reading. These hip measure repetitions are given only for each centimeter. For example, for a child with a width of hips of 27.8 we would look in the fourth row of the appropriate column in the block of figures designated by [27].

Table II is a two-way table giving partial values for any skeletal arrangement of chest dimensions. Readings are given in this table for .5 centimeter intervals for both measures. Here also the ordinate and abscissa of the tables are the lower limits of the interval. The ordinates in this table are likewise repeated for each centimeter after every fourth column.

Tables III, IV, V, and VI are similar in kind to Tables I and II. Table VII is a one-way table and needs no explanation.

* Tables for both sexes from ages seven to twelve have been prepared and may be obtained from the American Child Health Association, 370 Seventh Avenue, New York.

In Tables VIII, IX, and X are given the number of children in 1,000 who have residuals in arm girth, calf girth, and amount of subcutaneous tissue over the biceps that are less than any given residual. Therefore, a residual of 0 in each table, which is average, has a value of 500. Readings above 500 indicate an excess of the quality for the skeletal arrangement and readings below 500 indicate a deficiency. The degree of excess or deficiency may be judged from the amount that the readings from these tables deviate from 500. Extreme deviations in either direction are probably undesirable.

We will illustrate the use of the tables with actual measurements of a child. John is an eleven-year-old boy.* His measurements in units as described in Appendix A are: †

Height	53.5
Width of Hips	25.9
Chest Depth	30.5
Chest Breadth	44.4
Bisacromial Width	29.8
Arm Girth	42.4
Calf Girth	28.4
Biceps Subcutaneous Tissue	30.0

First we will determine the arm girth expectancy by using Tables I and II. In Table I the height readings occur for unit intervals and the hip readings are for intervals of .25. To obtain the reading for John we find the column headed 53. Following down in that column to the [25] we read the third reading below the [25] in the 53 column. We record the 10.1.

On Table II, in the column headed 30.5 and opposite the [44] we find the second reading 30.2, which we record. The sum of the

* As previously stated age is defined as having passed that birthday but not yet reached the next birthday, that is, an eleven-year-old boy is one who has passed his eleventh birthday and has not reached his twelfth birthday.

† Of course, these values do not represent the true chest breadth, chest depth, and arm girth, for they are the sum of two measurements of each of these qualities, but since we are interested only in differences between children, the formulæ and likewise the tables here given take into account these variations from the true values.

reading from Table I and the reading from Table II gives us the expected girth measure, i.e., 10.1 + 30.2 = 40.3. The difference between John's actual girth and the average girth expected from his bony structure represents his residual in arm girth. Since his actual girth is 42.4, John's residual in arm girth is 42.4 — 40.3, which is 2.1, meaning that John's girth as measured is greater than would be expected from his skeletal arrangement. But what does a residual of 2.1 mean? Is this a real deviation or one that is often found? How many children who are his peers have residuals as great or greater than this? To answer this question we have prepared Table VIII, which gives the number of children among 1,000 skeletal peers who have girths that are less than John's. Reading from this table we find that 813 out of 1,000 skeletal peers have girths less than John's.

John's arm girth, therefore, is considerably above the expected arm girth for his peers in skeletal arrangement.

In a similar manner from Tables III and IV we find the expected calf girth, thus:

Reading from Table III	13.6
Reading from Table IV	14.7
Expected Calf Girth	28.3
Actual Calf Girth as Measured	28.4
Residual in Calf Girth	.1

Reading from Table IX which is similar to Table VIII, we find that 500+ out of 1,000 who have a skeletal arrangement like John's possess less girth than he. Therefore John's calf girth is about average for boys of his age and skeletal dimensions. As Tables VIII and IX render the arm girth and calf girth residuals comparable, we can say that John has much larger arm muscles than calf muscles in proportion to his skeletal dimensions.

It has been shown in Chapter III that in addition to height, width

of hips, chest breadth, and chest depth, the bisacromial width is an important measure in the determination of the expected amount of subcutaneous tissue. Therefore, we have made three tables from which to determine the expected subcutaneous tissue. Tables V and VI are used in the same manner as Tables I and II. From the sum of the two readings obtained from Tables V and VI we *subtract* the reading that corresponds to the bisacromial width as given in Table VII.

Therefore, John's expected amount of subcutaneous tissue over the biceps is determined thus:

Reading from Table V	8.7
Reading from Table VI	26.3
Sum	35.0
Reading from Table VII	—8.3
Expected Amount of Subcutaneous Tissue	26.7
Actual Subcutaneous Tissue as Measured	30.0
Residual	3.3

By a reference to Table X we find that 794+ out of 1,000 skeletal peers have subcutaneous tissue residuals less than John.

We present one other illustrative case without explanation but with the details clearly indicated.

Henry is eleven years old and his measurements are:

Height	54.5
Width of Hips	25.9
Chest Depth	31.7
Chest Breadth	45.9
Bisacromial Width	30.3
Arm Girth	41.2
Calf Girth	28.8
Biceps Subcutaneous Tissue	28.0

His arm girth residual is:

Reading from Table I	10.0
Reading from Table II	31.5
Expected Arm Girth	41.5
Actual Arm Girth as Measured	41.2
Residual	—.3

Number in 1,000 who have a residual of less than —.3 = 449. He is less than average in this quality to a negligible degree.

His calf girth residual is:

Reading from Table III	13.6
Reading from Table IV	15.2
Expected Calf Girth	28.8
Actual Calf Girth as Measured	28.8
Residual	.0

Hence, he is just average in calf girth.

His biceps subcutaneous tissue residual is:

Reading from Table V	8.5
Reading from Table VI	27.7
Sum	36.2
Reading from Table VII	—8.5
Expected Biceps Subcutaneous Tissue	27.7
Actual Biceps Subcutaneous Tissue as Measured	28.0
Residual	.3

Number in 1,000 skeletal peers who have less amount of subcutaneous tissue over biceps = 500+.

He is average in this respect also.

Table I

TO BE USED IN CONJUNCTION WITH TABLE II FOR DETERMINATION OF UPPER ARM GIRTH EXPECTATION FROM SKELETAL MEASURES

(Eleven-Year-Old Boys)

HIPS	HEIGHT																					
	48.0	49.0	50.0	51.0	52.0		53.0	54.0	55.0	56.0	57.0		58.0	59.0	60.0	61.0	62.0		63.0	64.0	65.0	66.0	67.0
20.00	5.8	5.7	5.6	5.5	5.4	[20]	5.3	5.2	5.1	5.0	4.9	[20]	4.8	4.7	4.7	4.6	4.5	[20]	4.4	4.3	4.2	4.1	4.0
.25	6.0	5.9	5.8	5.7	5.6		5.5	5.4	5.3	5.2	5.1		5.0	5.0	4.9	4.8	4.7		4.6	4.5	4.4	4.3	4.2
.50	6.2	6.1	6.0	5.9	5.8		5.7	5.6	5.5	5.4	5.3		5.3	.5.2	5.1	5.0	4.9		4.8	4.7	4.6	4.5	4.4
.75	6.4	6.3	6.2	6.1	6.0		5.9	5.8	5.7	5.6	5.6		5.5	5.4	5.3	5.2	5.1		5.0	4.9	4.8	4.7	4.6
21.00	6.6	6.5	6.4	6.3	6.2	[21]	6.1	6.0	5.9	5.9	5.8	[21]	5.7	5.6	5.5	5.4	5.3	[21]	5.2	5.1	5.0	4.9	4.8
.25	6.8	6.7	6.6	6.5	6.4		6.3	6.2	6.2	6.1	6.0		5.9	5.8	5.7	5.6	5.5		5.4	5.3	5.2	5.1	5.1
.50	7.0	6.9	6.8	6.7	6.6		6.6	6.5	6.4	6.3	6.2		6.1	6.0	5.9	5.8	5.7		5.6	5.5	5.4	5.3	5.3
.75	7.2	7.1	7.0	6.9	6.9		6.8	6.7	6.6	6.5	6.4		6.3	6.2	6.1	6.0	5.9		5.8	5.7	5.7	5.6	5.5
22.00	7.4	7.3	7.2	7.2	7.1	[22]	7.0	6.9	6.8	6.7	6.6	[22]	6.5	6.4	6.3	6.2	6.1	[22]	6.0	6.0	5.9	5.8	5.7
.25	7.6	7.5	7.5	7.4	7.3		7.2	7.1	7.0	6.9	6.8		6.7	6.6	6.5	6.4	6.3		6.3	6.2	6.1	6.0	5.9
.50	7.8	7.8	7.7	7.6	7.5		7.4	7.3	7.2	7.1	7.0		6.9	6.8	6.7	6.6	6.6		6.5	6.4	6.3	6.2	6.1
.75	8.1	8.0	7.9	7.8	7.7		7.6	7.5	7.4	7.3	7.2		7.1	7.0	7.0	6.9	6.8		6.7	6.6	6.5	6.4	6.3
23.00	8.3	8.2	8.1	8.0	7.9	[23]	7.8	7.7	7.6	7.5	7.4	[23]	7.3	7.3	7.2	7.1	7.0	[23]	6.9	6.8	6.7	6.6	6.5
.25	8.5	8.4	8.3	8.2	8.1		8.0	7.9	7.8	7.7	7.6		7.6	7.5	7.4	7.3	7.2		7.1	7.0	6.9	6.8	6.7
.50	8.7	8.6	8.5	8.4	8.3		8.2	8.1	8.0	7.9	7.9		7.8	7.7	7.6	7.5	7.4		7.3	7.2	7.1	7.0	6.9
.75	8.9	8.8	8.7	8.6	8.5		8.4	8.3	8.2	8.2	8.1		8.0	7.9	7.8	7.7	7.6		7.5	7.4	7.3	7.2	7.1
24.00	9.1	9.0	8.9	8.8	8.7	[24]	8.6	8.5	8.5	8.4	8.3	[24]	8.2	8.1	8.0	7.9	7.8	[24]	7.7	7.6	7.5	7.4	7.3
.25	9.3	9.2	9.1	9.0	8.9		8.8	8.8	8.7	8.6	8.5		8.4	8.3	8.2	8.1	8.0		7.9	7.8	7.7	7.6	7.6
.50	9.5	9.4	9.3	9.2	9.1		9.1	9.0	8.9	8.8	8.7		8.6	8.5	8.4	8.3	8.2		8.1	8.0	8.0	7.8	7.8
.75	9.7	9.6	9.5	9.5	9.4		9.3	9.2	9.1	9.0	8.9		8.8	8.7	8.6	8.5	8.4		8.3	8.3	8.2	8.0	8.0
25.00	9.9	9.8	9.8	9.7	9.6	[25]	9.5	9.4	9.3	9.2	9.1	[25]	9.0	8.9	8.8	8.7	8.6	[25]	8.6	8.5	8.4	8.2	8.2
.25	10.1	10.1	10.0	9.9	9.8		9.7	9.6	9.5	9.4	9.3		9.2	9.1	9.0	8.9	8.9		8.8	8.7	8.6	8.5	8.4
.50	10.4	10.3	10.2	10.1	10.0		9.9	9.8	9.7	9.6	9.5		9.4	9.3	9.2	9.2	9.1		9.0	8.9	8.8	8.7	8.6
.75	10.6	10.5	10.4	10.3	10.2		10.1	10.0	9.9	9.8	9.7		9.6	9.5	9.5	9.4	9.3		9.2	9.1	9.0	8.9	8.8
26.00	10.8	10.7	10.6	10.5	10.4	[26]	10.3	10.2	10.1	10.0	9.9	[26]	9.8	9.8	9.7	9.6	9.5	[26]	9.4	9.3	9.2	9.1	9.0
.25	11.0	10.9	10.8	10.7	10.6		10.5	10.4	10.3	10.2	10.2		10.1	10.0	9.9	9.8	9.7		9.6	9.5	9.4	9.3	9.2
.50	11.2	11.1	11.0	10.9	10.8		10.7	10.6	10.5	10.5	10.4		10.3	10.2	10.1	10.0	9.9		9.8	9.7	9.6	9.5	9.4
.75	11.4	11.3	11.2	11.1	11.0		10.9	10.8	10.8	10.7	10.6		10.5	10.4	10.3	10.2	10.1		10.0	9.9	9.8	9.7	9.6
27.00	11.6	11.5	11.4	11.3	11.2	[27]	11.1	11.1	11.0	10.9	10.8	[27]	10.7	10.6	10.5	10.4	10.3	[27]	10.2	10.1	10.0	9.9	9.9
.25	11.8	11.7	11.6	11.5	11.4		11.4	11.3	11.2	11.1	11.0		10.9	10.8	10.7	10.6	10.5		10.4	10.3	10.2	10.2	10.1
.50	12.0	11.9	11.8	11.7	11.7		11.6	11.5	11.4	11.3	11.2		11.1	11.0	10.9	10.8	10.7		10.6	10.6	10.5	10.4	10.3
.75	12.2	12.1	12.0	12.0	11.9		11.8	11.7	11.6	11.5	11.4		11.3	11.2	11.1	11.0	10.9		10.9	10.8	10.7	10.6	10.5
28.00	12.4	12.3	12.3	12.2	12.1	[28]	12.0	11.9	11.8	11.7	11.6	[28]	11.5	11.4	11.3	11.2	11.2	[28]	11.1	11.0	10.9	10.8	10.7
.25	12.7	12.6	12.5	12.4	12.3		12.2	12.1	12.0	11.9	11.8		11.7	11.6	11.5	11.5	11.4		11.3	11.2	11.1	11.0	10.9
.50	12.9	12.8	12.7	12.6	12.5		12.4	12.3	12.2	12.1	12.0		11.9	11.8	11.8	11.7	11.6		11.5	11.4	11.3	11.2	11.1
.75	13.1	13.0	12.9	12.8	12.7		12.6	12.5	12.4	12.3	12.2		12.1	12.1	12.0	11.9	11.8		11.7	11.6	11.5	11.4	11.3
29.00	13.3	13.2	13.1	13.0	12.9	[29]	12.8	12.7	12.6	12.5	12.4	[29]	12.4	12.3	12.2	12.1	12.0	[29]	11.9	11.8	11.7	11.6	11.5
.25	13.5	13.4	13.3	13.2	13.1		13.0	12.9	12.8	12.7	12.7		12.6	12.5	12.4	12.3	12.2		12.1	12.0	11.9	11.8	11.7
.50	13.7	13.6	13.5	13.4	13.3		13.2	13.1	13.1	13.0	12.9		12.8	12.7	12.6	12.5	12.4		12.3	12.2	12.1	12.0	11.9
.75	13.9	13.8	13.7	13.6	13.5		13.4	13.4	13.3	13.2	13.1		13.0	12.9	12.8	12.7	12.6		12.5	12.4	12.3	12.2	12.2
30.00	14.1	14.0	13.9	13.8	13.7	[30]	13.7	13.6	13.5	13.4	13.3	[30]	13.2	13.1	13.0	12.9	12.8	[30]	12.7	12.6	12.5	12.5	12.4
.25	14.3	14.2	14.1	14.0	14.0		13.9	13.8	13.7	13.6	13.5		13.4	13.3	13.2	13.1	13.0		12.9	12.8	12.8	12.7	12.6
.50	14.5	14.4	14.3	14.3	14.2		14.1	14.0	13.9	13.8	13.7		13.6	13.5	13.4	13.3	13.2		13.1	13.1	13.0	12.9	12.8
.75	14.7	14.6	14.6	14.5	14.4		14.3	14.2	14.1	14.0	13.9		13.8	13.7	13.6	13.5	13.4		13.4	13.3	13.2	13.1	13.0

Table II

TO BE USED IN CONJUNCTION WITH TABLE I FOR DETERMINATION OF UPPER ARM GIRTH EXPECTATION FROM SKELETAL MEASURES

(Eleven-Year-Old Boys)

CHEST BREADTH	CHEST DEPTH																		
	24.0	24.5	25.0	25.5	26.0	26.5		27.0	27.5	28.0	28.5	29.0	29.5		30.0	30.5	31.0	31.5	32.0	32.5
35.0	22.2	22.5	22.8	23.1	23.5	23.8	[35]	24.1	24.4	24.7	25.0	25.4	25.7	[35]	26.0	26.3	26.6	26.9	27.2	27.6
.5	22.4	22.7	23.0	23.4	23.7	24.0		24.3	24.6	24.9	25.3	25.6	25.9		26.2	26.5	26.8	27.1	27.5	27.8
36.0	22.6	22.9	23.3	23.6	23.9	24.2	[36]	24.5	24.8	25.2	25.5	25.8	26.1	[36]	26.4	26.7	27.0	27.4	27.7	28.0
.5	22.8	23.2	23.5	23.8	24.1	24.4		24.7	25.1	25.4	25.7	26.0	26.3		26.6	26.9	27.3	27.6	27.9	28.2
37.0	23.1	23.4	23.7	24.0	24.3	24.6	[37]	25.0	25.3	25.6	25.9	26.2	26.5	[37]	26.8	27.2	27.5	27.8	28.1	28.4
.5	23.3	23.6	23.9	24.2	24.5	24.9		25.2	25.5	25.8	26.1	26.4	26.8		27.1	27.4	27.7	28.0	28.3	28.6
38.0	23.5	23.8	24.1	24.4	24.8	25.1	[38]	25.4	25.7	26.0	26.3	26.7	27.0	[38]	27.3	27.6	27.9	28.2	28.5	28.9
.5	23.7	24.0	24.3	24.7	25.0	25.3		25.6	25.9	26.2	26.6	26.9	27.2		27.5	27.8	28.1	28.4	28.8	29.1
39.0	23.9	24.2	24.6	24.9	25.2	25.5	[39]	25.8	26.1	26.5	26.8	27.1	27.4	[39]	27.7	28.0	28.3	28.7	29.0	29.3
.5	24.1	24.5	24.8	25.1	25.4	25.7		26.0	26.4	26.7	27.0	27.3	27.6		27.9	28.2	28.6	28.9	29.2	29.5
40.0	24.4	24.7	25.0	25.3	25.6	25.9	[40]	26.3	26.6	26.9	27.2	27.5	27.8	[40]	28.1	28.5	28.8	29.1	29.4	29.7
.5	24.6	24.9	25.2	25.5	25.8	26.2		26.5	26.8	27.1	27.4	27.7	28.0		28.4	28.7	29.0	29.3	29.6	29.9
41.0	24.8	25.1	25.4	25.7	26.1	26.4	[41]	26.7	27.0	27.3	27.6	27.9	28.3	[41]	28.6	28.9	29.2	29.5	29.8	30.2
.5	25.0	25.3	25.6	26.0	26.3	26.6		26.9	27.2	27.5	27.8	28.2	28.5		28.8	29.1	29.4	29.7	30.1	30.4
42.0	25.2	25.5	25.9	26.2	26.5	26.8	[42]	27.1	27.4	27.7	28.1	28.4	28.7	[42]	29.0	29.3	29.6	30.0	30.3	30.6
.5	25.4	25.8	26.1	26.4	26.7	27.0		27.3	27.6	28.0	28.3	28.6	28.9		29.2	29.5	29.9	30.2	30.5	30.8
43.0	25.7	26.0	26.3	26.6	26.9	27.2	[43]	27.6	27.9	28.2	28.5	28.8	29.1	[43]	29.4	29.8	30.1	30.4	30.7	31.0
.5	25.9	26.2	26.5	26.8	27.1	27.5		27.8	28.1	28.4	28.7	29.0	29.3		29.7	30.0	30.3	30.6	30.9	31.2
44.0	26.1	26.4	26.7	27.0	27.4	27.7	[44]	28.0	28.3	28.6	28.9	29.2	29.6	[44]	29.9	30.2	30.5	30.8	31.1	31.5
.5	26.3	26.6	26.9	27.3	27.6	27.9		28.2	28.5	28.8	29.1	29.5	29.8		30.1	30.4	30.7	31.0	31.4	31.7
45.0	26.5	26.8	27.2	27.5	27.8	28.1	[45]	28.4	28.7	29.0	29.4	29.7	30.0	[45]	30.3	30.6	30.9	31.3	31.6	31.9
.5	26.7	27.1	27.4	27.7	28.0	28.3		28.6	28.9	29.3	29.6	29.9	30.2		30.5	30.8	31.2	31.5	31.8	32.1
46.0	27.0	27.3	27.6	27.9	28.2	28.5	[46]	28.8	29.2	29.5	29.8	30.1	30.4	[46]	30.7	31.1	31.4	31.7	32.0	32.3
.5	27.2	27.5	27.8	28.1	28.4	28.7		29.1	29.4	29.7	30.0	30.3	30.6		31.0	31.3	31.6	31.9	32.2	32.5
47.0	27.4	27.7	28.0	28.3	28.6	29.0	[47]	29.3	29.6	29.9	30.2	30.5	30.9	[47]	31.2	31.5	31.8	32.1	32.4	32.8
.5	27.6	27.9	28.2	28.5	28.9	29.2		29.5	29.8	30.1	30.4	30.8	31.1		31.4	31.7	32.0	32.3	32.7	33.0
48.0	27.8	28.1	28.5	28.8	29.1	29.4	[48]	29.7	30.0	30.3	30.7	31.0	31.3	[48]	31.6	31.9	32.2	32.6	32.9	33.2
.5	28.0	28.4	28.7	29.0	29.3	29.6		29.9	30.2	30.6	30.9	31.2	31.5		31.8	32.1	32.5	32.8	33.1	33.4
49.0	28.3	28.6	28.9	29.2	29.5	29.8	[49]	30.1	30.5	30.8	31.1	31.4	31.7	[49]	32.0	32.4	32.7	33.0	33.3	33.6
.5	28.5	28.8	29.1	29.4	29.7	30.0		30.4	30.7	31.0	31.3	31.6	31.9		32.3	32.6	32.9	33.2	33.5	33.8
50.0	28.7	29.0	29.3	29.6	29.9	30.3	[50]	30.6	30.9	31.2	31.5	31.8	32.2	[50]	32.5	32.8	33.1	33.4	33.7	34.1
.5	28.9	29.2	29.5	29.8	30.2	30.5		30.8	31.1	31.4	31.7	32.1	32.4		32.7	33.0	33.3	33.6	34.0	34.3
51.0	29.1	29.4	29.7	30.1	30.4	30.7	[51]	31.0	31.3	31.6	32.0	32.3	32.6	[51]	32.9	32.2	33.5	33.9	34.2	34.5
.5	29.3	29.6	30.0	30.3	30.6	30.9		31.2	31.5	31.9	32.2	32.5	32.8		33.1	33.4	33.8	34.1	34.4	34.7
52.0	29.5	29.9	30.2	30.5	30.8	31.1	[52]	31.4	31.8	32.1	32.4	32.7	33.0	[52]	33.3	33.7	34.0	34.3	34.6	34.9
.5	29.8	30.1	30.4	30.7	31.0	31.3		31.7	32.0	32.3	32.6	32.9	33.2		33.6	33.9	34.2	34.5	34.8	35.1

Table II—(*Continued*)

TO BE USED IN CONJUNCTION WITH TABLE I FOR DETERMINATION OF UPPER ARM GIRTH EXPECTATION FROM SKELETAL MEASURES

(Eleven-Year-Old Boys)

CHEST BREADTH	CHEST DEPTH																		
	33.0	33.5	34.0	34.5	35.0	35.5		36.0	36.5	37.0	37.5	38.0	38.5		39.0	39.5	40.0	40.5	41.0	41.5
35.0	27.9	28.2	28.5	28.8	29.1	29.5	[35]	29.8	30.1	30.4	30.7	31.0	31.4	[35]	31.7	32.0	32.3	32.6	32.9	33.3
.5	28.1	28.4	28.7	29.0	29.4	29.7		30.0	30.3	30.6	30.9	31.3	31.6		31.9	32.2	32.5	32.8	33.2	33.5
36.0	28.3	28.6	28.9	29.3	29.6	29.9	[36]	30.2	30.5	30.8	31.2	31.5	31.8	[36]	32.1	32.4	32.7	33.1	33.4	33.7
.5	28.5	28.8	29.2	29.5	29.8	30.1		30.4	30.7	31.1	31.4	31.7	32.0		32.3	32.6	33.0	33.3	33.6	33.9
37.0	28.7	29.1	29.4	29.7	30.0	30.3	[37]	30.6	31.0	31.3	31.6	31.9	32.2	[37]	32.5	32.9	33.2	33.5	33.8	34.1
.5	29.0	29.3	29.6	30.0	30.2	30.5		30.9	31.2	31.5	31.8	32.1	32.4		32.8	33.1	33.4	33.7	34.0	34.3
38.0	29.2	29.5	29.8	30.1	30.4	30.8	[38]	31.1	31.4	31.7	32.0	32.3	32.7	[38]	33.0	33.3	33.6	33.9	34.2	34.5
.5	29.4	29.7	30.0	30.3	30.7	31.0		31.3	31.6	31.9	32.2	32.6	32.9		33.2	33.5	33.8	34.1	34.5	34.8
39.0	29.6	29.9	30.2	30.6	30.9	31.2	[39]	31.5	31.8	32.1	32.5	32.8	33.1	[39]	33.4	33.7	34.0	34.4	34.7	35.0
.5	29.8	30.1	30.5	30.8	31.1	31.4		31.7	32.0	32.4	32.7	33.0	33.3		33.6	33.9	34.3	34.6	34.9	35.2
40.0	30.0	30.4	30.7	31.0	31.3	31.6	[40]	31.9	32.3	32.6	32.9	33.2	33.5	[40]	33.8	34.2	34.5	34.8	35.1	35.4
.5	30.3	30.6	30.9	31.2	31.5	31.8		32.2	32.5	32.8	33.1	33.4	33.7		34.1	34.4	34.7	35.0	35.3	35.6
41.0	30.5	30.8	31.1	31.4	31.7	32.1	[41]	32.4	32.7	33.0	33.3	33.6	34.0	[41]	34.3	34.6	34.9	35.2	35.5	35.8
.5	30.7	31.0	31.3	31.6	32.0	32.3		32.6	32.9	33.2	33.5	33.9	34.2		34.5	34.8	35.1	35.4	35.7	36.1
42.0	30.9	31.2	31.5	31.9	32.2	32.5	[42]	32.8	33.1	33.4	33.8	34.1	34.4	[42]	34.7	35.0	35.3	35.6	36.0	36.3
.5	31.1	31.4	31.8	32.1	32.4	32.7		33.0	33.3	33.7	34.0	34.3	34.6		34.9	35.2	35.5	35.9	36.2	36.5
43.0	31.3	31.7	32.0	32.3	32.6	32.9	[43]	33.2	33.6	33.9	34.2	34.5	34.8	[43]	35.1	35.4	35.8	36.1	36.4	36.7
.5	31.6	31.9	32.2	32.5	32.8	33.1		33.5	33.8	34.1	34.4	34.7	35.0		35.4	35.7	36.0	36.3	36.6	36.9
44.0	31.8	32.1	32.4	32.7	33.0	33.4	[44]	33.7	34.0	34.3	34.6	34.9	35.3	[44]	35.6	35.9	36.2	36.5	36.8	37.1
.5	32.0	32.3	32.6	32.9	33.3	33.6		33.9	34.2	34.5	34.8	35.2	35.5		35.8	36.1	36.4	36.7	37.0	37.4
45.0	32.2	32.5	32.8	33.2	33.5	33.8	[45]	34.1	34.4	34.7	35.1	35.4	35.7	[45]	36.0	36.3	36.6	36.9	37.3	37.6
.5	32.4	32.7	33.1	33.4	33.7	34.0		34.3	34.6	35.0	35.3	35.6	35.9		36.2	36.5	36.8	37.2	37.5	37.8
46.0	32.6	33.0	33.3	33.6	33.9	34.2	[46]	34.5	34.9	35.2	35.5	35.8	36.1	[46]	36.4	36.7	37.1	37.4	37.7	38.0
.5	32.9	33.2	33.5	33.8	34.1	34.4		34.8	35.1	35.4	35.7	36.0	36.3		36.6	37.0	37.3	37.6	37.9	38.2
47.0	33.1	33.4	33.7	34.0	34.3	34.7	[47]	35.0	35.3	35.6	35.9	36.2	36.5	[47]	36.9	37.2	37.5	37.8	38.1	38.4
.5	33.3	33.6	33.9	34.2	34.6	34.9		35.2	35.5	35.8	36.1	36.4	36.8		37.1	37.4	37.7	38.0	38.3	38.7
48.0	33.5	33.8	34.1	34.5	34.8	35.1	[48]	35.4	35.7	36.0	36.3	36.7	37.0	[48]	37.3	37.6	37.9	38.2	38.6	38.9
.5	33.7	34.0	34.4	34.7	35.0	35.3		35.6	35.9	36.3	36.6	36.9	37.2		37.5	37.8	38.1	38.5	38.8	39.1
49.0	33.9	34.3	34.6	34.9	35.2	35.5	[49]	35.8	36.2	36.5	36.8	37.1	37.4	[49]	37.7	38.0	38.4	38.7	39.0	39.3
.5	34.2	34.5	34.8	35.1	35.4	35.7		36.1	36.4	36.7	37.0	37.3	37.6		37.9	38.3	38.6	38.9	39.2	39.5
50.0	34.4	34.7	35.0	35.3	35.6	36.0	[50]	36.3	36.6	36.9	37.2	37.5	37.8	[50]	38.2	38.5	38.8	39.1	39.4	39.7
.5	34.6	34.9	35.2	35.5	35.9	36.2		36.5	36.8	37.1	37.4	37.7	38.1		38.4	38.7	39.0	39.3	39.6	40.0
51.0	34.8	35.1	35.4	35.8	36.1	36.4	[51]	36.7	37.0	37.3	37.6	38.0	38.3	[51]	38.6	38.9	39.2	39.5	39.9	40.2
.5	35.0	35.3	35.7	36.0	36.3	36.6		36.9	37.2	37.5	37.9	38.2	38.5		38.8	39.1	39.4	39.8	40.1	40.4
52.0	35.2	35.6	35.9	36.2	36.5	36.8	[52]	37.1	37.4	37.8	38.1	38.4	38.7	[52]	39.0	39.3	39.7	40.0	40.3	40.6
.5	35.5	35.8	36.1	36.4	36.7	37.0		37.3	37.7	38.0	38.3	38.6	38.9		39.2	39.6	39.9	40.2	40.5	40.8

Table III

TO BE USED IN CONJUNCTION WITH TABLE IV FOR DETERMINATION OF CALF GIRTH EXPECTATION FROM SKELETAL MEASURES

(Eleven-Year-Old Boys)

HIPS	HEIGHT																				
	48.0	49.0	50.0	51.0	52.0		53.0	54.0	55.0	56.0	57.0		58.0	59.0	60.0	61.0	62.0		63.0	64.0	65.0	66.0	67.0
20.00	10.5	10.5	10.5	10.6	10.6	[20]	10.6	10.6	10.7	10.7	10.7	[20]	10.8	10.8	10.8	10.9	10.9	[20]	10.9	11.0	11.0	11.0	11.1
.25	10.6	10.6	10.6	10.7	10.7		10.7	10.8	10.8	10.8	10.9		10.9	10.9	11.0	11.0	11.0		11.1	11.1	11.1	11.2	11.2
.50	10.7	10.7	10.8	10.8	10.8		10.9	10.9	10.9	11.0	11.0		11.0	11.1	11.1	11.1	11.2		11.2	11.2	11.3	11.3	11.3
.75	10.8	10.9	10.9	10.9	11.0		11.0	11.0	11.1	11.1	11.1		11.2	11.2	11.2	11.3	11.3		11.3	11.3	11.4	11.4	11.4
21.00	11.0	11.0	11.0	11.1	11.1	[21]	11.1	11.2	11.2	11.2	11.3	[21]	11.3	11.3	11.4	11.4	11.4	[21]	11.4	11.5	11.5	11.5	11.6
.25	11.1	11.1	11.2	11.2	11.2		11.3	11.3	11.3	11.4	11.4		11.4	11.4	11.5	11.5	11.5		11.6	11.6	11.6	11.7	11.7
.50	11.2	11.3	11.3	11.3	11.4		11.4	11.4	11.5	11.5	11.5		11.5	11.6	11.6	11.6	11.7		11.7	11.7	11.8	11.8	11.8
.75	11.4	11.4	11.4	11.5	11.5		11.5	11.5	11.6	11.6	11.6		11.7	11.7	11.7	11.8	11.8		11.8	11.9	11.9	11.9	12.0
22.00	11.5	11.5	11.6	11.6	11.6	[22]	11.6	11.7	11.7	11.7	11.8	[22]	11.8	11.8	11.9	11.9	11.9	[22]	12.0	12.0	12.0	12.1	12.1
.25	11.6	11.6	11.7	11.7	11.7		11.8	11.8	11.8	11.9	11.9		11.9	12.0	12.0	12.0	12.1		12.1	12.1	12.2	12.2	12.2
.50	11.7	11.8	11.8	11.8	11.9		11.9	11.9	12.0	12.0	12.0		12.1	12.1	12.1	12.2	12.2		12.2	12.3	12.3	12.3	12.3
.75	11.9	11.9	11.9	12.0	12.0		12.0	12.1	12.1	12.1	12.2		12.2	12.2	12.3	12.3	12.3		12.3	12.4	12.4	12.4	12.5
23.00	12.0	12.0	12.1	12.1	12.1	[23]	12.2	12.2	12.2	12.3	12.3	[23]	12.3	12.4	12.4	12.4	12.4	[23]	12.5	12.5	12.5	12.6	12.6
.25	12.1	12.2	12.2	12.2	12.3		12.3	12.3	12.4	12.4	12.4		12.4	12.5	12.5	12.5	12.6		12.6	12.6	12.7	12.7	12.7
.50	12.3	12.3	12.3	12.4	12.4		12.4	12.5	12.5	12.5	12.5		12.6	12.6	12.6	12.7	12.7		12.7	12.8	12.8	12.8	12.9
.75	12.4	12.4	12.5	12.5	12.5		12.5	12.6	12.6	12.6	12.7		12.7	12.7	12.8	12.8	12.8		12.9	12.9	12.9	13.0	13.0
24.00	12.5	12.6	12.6	12.6	12.6	[24]	12.7	12.7	12.7	12.8	12.8	[24]	12.8	12.9	12.9	12.9	13.0	[24]	13.0	13.0	13.1	13.1	13.1
.25	12.6	12.7	12.7	12.7	12.8		12.8	12.8	12.9	12.9	12.9		13.0	13.0	13.0	13.1	13.1		13.1	13.2	13.2	13.2	13.2
.50	12.8	12.8	12.8	12.9	12.9		12.9	13.0	13.0	13.0	13.1		13.1	13.1	13.2	13.2	13.2		13.3	13.3	13.3	13.3	13.4
.75	12.9	12.9	13.0	13.0	13.0		13.1	13.1	13.1	13.2	13.2		13.2	13.3	13.3	13.3	13.3		13.4	13.4	13.4	13.5	13.5
25.00	13.0	13.1	13.1	13.1	13.2	[25]	13.2	13.2	13.3	13.3	13.3	[25]	13.4	13.4	13.4	13.4	13.5	[25]	13.5	13.5	13.6	13.6	13.6
.25	13.2	13.2	13.2	13.3	13.3		13.3	13.4	13.4	13.4	13.4		13.5	13.5	13.5	13.6	13.6		13.6	13.7	13.7	13.7	13.8
.50	13.3	13.3	13.4	13.4	13.4		13.5	13.5	13.5	13.5	13.6		13.6	13.6	13.7	13.7	13.7		13.8	13.8	13.8	13.9	13.9
.75	13.4	13.5	13.5	13.5	13.5		13.6	13.6	13.6	13.7	13.7		13.7	13.8	13.8	13.8	13.9		13.9	13.9	14.0	14.0	14.0
26.00	13.6	13.6	13.6	13.6	13.7	[26]	13.7	13.7	13.8	13.8	13.8	[26]	13.9	13.9	13.9	14.0	14.0	[26]	14.0	14.1	14.1	14.1	14.2
.25	13.7	13.7	13.7	13.8	13.8		13.8	13.9	13.9	13.9	14.0		14.0	14.0	14.1	14.1	14.1		14.2	14.2	14.2	14.2	14.3
.50	13.8	13.8	13.9	13.9	13.9		14.0	14.0	14.0	14.1	14.1		14.1	14.2	14.2	14.2	14.3		14.3	14.3	14.3	14.4	14.4
.75	13.9	14.0	14.0	14.0	14.1		14.1	14.1	14.2	14.2	14.2		14.3	14.3	14.3	14.3	14.4		14.4	14.4	14.5	14.5	14.5
27.00	14.1	14.1	14.1	14.2	14.2	[27]	14.2	14.3	14.3	14.3	14.4	[27]	14.4	14.4	14.4	14.5	14.5	[27]	14.5	14.6	14.6	14.6	14.7
.25	14.2	14.2	14.3	14.3	14.3		14.4	14.4	14.4	14.4	14.5		14.5	14.5	14.6	14.6	14.6		14.7	14.7	14.7	14.8	14.8
.50	14.3	14.4	14.4	14.4	14.5		14.5	14.5	14.5	14.6	14.6		14.6	14.7	14.7	14.7	14.8		14.8	14.8	14.9	14.9	14.9
.75	14.5	14.5	14.5	14.5	14.6		14.6	14.6	14.7	14.7	14.7		14.8	14.8	14.8	14.9	14.9		14.9	15.0	15.0	15.0	15.1
28.00	14.6	14.6	14.6	14.7	14.7	[28]	14.7	14.8	14.8	14.8	14.9	[28]	14.9	14.9	15.0	15.0	15.0	[28]	15.1	15.1	15.1	15.2	15.2
.25	14.7	14.7	14.8	14.8	14.8		14.9	14.9	14.9	15.0	15.0		15.0	15.1	15.1	15.1	15.2		15.2	15.2	15.2	15.3	15.3
.50	14.8	14.9	14.9	14.9	15.0		15.0	15.0	15.1	15.1	15.1		15.2	15.2	15.2	15.3	15.3		15.3	15.3	15.4	15.4	15.4
.75	15.0	15.0	15.0	15.1	15.1		15.1	15.2	15.2	15.2	15.3		15.3	15.3	15.3	15.4	15.4		15.4	15.5	15.5	15.5	15.6
29.00	15.1	15.1	15.2	15.2	15.2	[29]	15.3	15.3	15.3	15.4	15.4	[29]	15.4	15.4	15.5	15.5	15.5	[29]	15.6	15.6	15.6	15.7	15.7
.25	15.2	15.3	15.3	15.3	15.4		15.4	15.4	15.4	15.5	15.5		15.5	15.6	15.6	15.6	15.7		15.7	15.7	15.8	15.8	15.8
.50	15.4	15.4	15.4	15.5	15.5		15.5	15.5	15.6	15.6	15.6		15.7	15.7	15.7	15.8	15.8		15.8	15.9	15.9	15.9	16.0
.75	15.5	15.5	15.5	15.6	15.6		15.6	15.7	15.7	15.7	15.8		15.8	15.8	15.9	15.9	15.9		16.0	16.0	16.0	16.1	16.1
30.00	15.6	15.6	15.7	15.7	15.7	[30]	15.8	15.8	15.8	15.9	15.9	[30]	15.9	16.0	16.0	16.0	16.1	[30]	16.1	16.1	16.2	16.2	16.2
.25	15.7	15.8	15.8	15.8	15.9		15.9	15.9	16.0	16.0	16.0		16.1	16.1	16.1	16.2	16.2		16.2	16.2	16.3	16.3	16.3
.50	15.9	15.9	15.9	16.0	16.0		16.0	16.1	16.1	16.1	16.2		16.2	16.2	16.3	16.3	16.3		16.3	16.4	16.4	16.4	16.5
.75	16.0	16.0	16.1	16.1	16.1		16.2	16.2	16.2	16.3	16.3		16.3	16.3	16.4	16.4	16.4		16.5	16.5	16.5	16.6	16.6

Table IV

TO BE USED IN CONJUNCTION WITH TABLE III FOR DETERMINATION OF CALF GIRTH EXPECTATION FROM SKELETAL MEASURES

(Eleven-Year-Old Boys)

CHEST BREADTH	CHEST DEPTH																		
	24.0	24.5	25.0	25.5	26.0	26.5		27.0	27.5	28.0	28.5	29.0	29.5		30.0	30.5	31.0	31.5	32.0	32.5
35.0	11.4	11.5	11.6	11.7	11.9	12.0	[35]	12.1	12.2	12.4	12.5	12.6	12.7	[35]	12.9	13.0	13.1	13.2	13.4	13.5
.5	11.5	11.6	11.7	11.8	12.0	12.1		12.2	12.3	12.5	12.6	12.7	12.8		13.0	13.1	13.2	13.3	13.5	13.6
36.0	11.5	11.7	11.8	11.9	12.0	12.2	[36]	12.3	12.4	12.5	12.7	12.8	12.9	[36]	13.0	13.2	13.3	13.4	13.5	13.7
.5	11.6	11.8	11.9	12.0	12.1	12.3		12.4	12.5	12.6	12.8	12.9	13.0		13.1	13.3	13.4	13.5	13.6	13.8
37.0	11.7	11.9	12.0	12.1	12.2	12.4	[37]	12.5	12.6	12.7	12.9	13.0	13.1	[37]	13.2	13.4	13.5	13.6	13.7	13.9
.5	11.8	11.9	12.1	12.2	12.3	12.4		12.6	12.7	12.8	12.9	13.1	13.2		13.3	13.4	13.6	13.7	13.8	13.9
38.0	11.9	12.0	12.2	12.3	12.4	12.5	[38]	12.7	12.8	12.9	13.0	13.2	13.3	[38]	13.4	13.5	13.7	13.8	13.9	14.0
.5	12.0	12.1	12.3	12.4	12.5	12.6		12.8	12.9	13.0	13.1	13.3	13.4		13.5	13.6	13.8	13.9	14.0	14.1
39.0	12.1	12.2	12.4	12.5	12.6	12.7	[39]	12.9	13.0	13.1	13.2	13.4	13.5	[39]	13.6	13.7	13.9	14.0	14.1	14.2
.5	12.2	12.3	12.4	12.6	12.7	12.8		12.9	13.1	13.2	13.3	13.4	13.6		13.7	13.8	13.9	14.1	14.2	14.3
40.0	12.3	12.4	12.5	12.7	12.8	12.9	[40]	13.0	13.2	13.3	13.4	13.5	13.7	[40]	13.8	13.9	14.0	14.2	14.3	14.4
.5	12.4	12.5	12.6	12.8	12.9	13.0		13.1	13.3	13.4	13.5	13.6	13.8		13.9	14.0	14.1	14.3	14.4	14.5
41.0	12.5	12.6	12.7	12.8	13.0	13.1	[41]	13.2	13.3	13.5	13.6	13.7	13.8	[41]	14.0	14.1	14.2	14.3	14.5	14.6
.5	12.6	12.7	12.8	12.9	13.1	13.2		13.3	13.4	13.6	13.7	13.8	13.9		14.1	14.2	14.3	14.4	14.6	14.7
42.0	12.7	12.8	12.9	13.0	13.2	13.3	[42]	13.4	13.5	13.7	13.8	13.9	14.0	[42]	14.2	14.3	14.4	14.5	14.7	14.8
.5	12.8	12.9	13.0	13.1	13.3	13.4		13.5	13.6	13.8	13.9	14.0	14.1		14.3	14.4	14.5	14.6	14.8	14.9
43.0	12.8	13.0	13.1	13.2	13.3	13.5	[43]	13.6	13.7	13.8	14.0	14.1	14.2	[43]	14.3	14.5	14.6	14.7	14.8	15.0
.5	12.9	13.1	13.2	13.3	13.4	13.6		13.7	13.8	13.9	14.1	14.2	14.3		14.4	14.6	14.7	14.8	14.9	15.1
44.0	13.0	13.2	13.3	13.4	13.5	13.7	[44]	13.8	13.9	14.0	14.2	14.3	14.4	[44]	14.5	14.7	14.8	14.9	15.0	15.2
.5	13.1	13.2	13.4	13.5	13.6	13.7		13.9	14.0	14.1	14.2	14.4	14.5		14.6	14.7	14.9	15.0	15.1	15.2
45.0	13.2	13.3	13.5	13.6	13.7	13.8	[45]	14.0	14.1	14.2	14.3	14.5	14.6	[45]	14.7	14.8	15.0	15.1	15.2	15.3
.5	13.3	13.4	13.6	13.7	13.8	13.9		14.1	14.2	14.3	14.4	14.6	14.7		14.8	14.9	15.1	15.2	15.3	15.4
46.0	13.4	13.5	13.7	13.8	13.9	14.0	[46]	14.2	14.3	14.4	14.5	14.6	14.8	[46]	14.9	15.0	15.1	15.3	15.4	15.5
.5	13.5	13.6	13.7	13.9	14.0	14.1		14.2	14.4	14.5	14.6	14.7	14.9		15.0	15.1	15.2	15.4	15.5	15.6
47.0	13.6	13.7	13.8	14.0	14.1	14.2	[47]	14.3	14.5	14.6	14.7	14.8	15.0	[47]	15.1	15.2	15.3	15.5	15.6	15.7
.5	13.7	13.8	13.9	14.1	14.2	14.3		14.4	14.6	14.7	14.8	14.9	15.1		15.2	15.3	15.4	15.6	15.7	15.8
48.0	13.8	13.9	14.0	14.1	14.3	14.4	[48]	14.5	14.6	14.8	14.9	15.0	15.1	[48]	15.3	15.4	15.5	15.6	15.8	15.9
.5	13.9	14.0	14.1	14.2	14.4	14.5		14.6	14.7	14.9	15.0	15.1	15.2		15.4	15.5	15.6	15.7	15.9	16.0
49.0	14.0	14.1	14.2	14.3	14.5	14.6	[49]	14.7	14.8	15.0	15.1	15.2	15.3	[49]	15.5	15.6	15.7	15.8	16.0	16.1
.5	14.1	14.2	14.3	14.4	14.5	14.7		14.8	14.9	15.0	15.2	15.3	15.4		15.5	15.7	15.8	15.9	16.0	16.2
50.0	14.1	14.3	14.4	14.5	14.6	14.8	[50]	14.9	15.0	15.1	15.3	15.4	15.5	[50]	15.6	15.8	15.9	16.0	16.1	16.3
.5	14.2	14.4	14.5	14.6	14.7	14.9		15.0	15.1	15.2	15.4	15.5	15.6		15.7	15.9	16.0	16.1	16.2	16.4
51.0	14.3	14.5	14.6	14.7	14.8	15.0	[51]	15.1	15.2	15.3	15.5	15.6	15.7	[51]	15.8	16.0	16.1	16.2	16.3	16.5
.5	14.4	14.5	14.7	14.8	14.9	15.0		15.2	15.3	15.4	15.5	15.7	15.8		15.9	16.0	16.2	16.3	16.4	16.5
52.0	14.5	14.6	14.8	14.9	15.0	15.1	[52]	15.3	15.4	15.5	15.6	15.8	15.9	[52]	16.0	16.1	16.3	16.4	16.5	16.6
.5	14.6	14.7	14.9	15.0	15.1	15.2		15.4	15.5	15.6	15.7	15.9	16.0		16.1	16.2	16.4	16.5	16.6	16.7

Continued on next page

Table IV—(*Continued*)

TO BE USED IN CONJUNCTION WITH TABLE III FOR DETERMINATION OF CALF GIRTH EXPECTATION FROM SKELETAL MEASURES

(Eleven-Year-Old Boys)

CHEST BREADTH	CHEST DEPTH																		
	33.0	33.5	34.0	34.5	35.0	35.5		36.0	36.5	37.0	37.5	38.0	38.5		39.0	39.5	40.0	40.5	41.0	41.5
35.0	13.6	13.7	13.9	14.0	14.1	14.2	[35]	14.4	14.5	14.6	14.7	14.9	15.0	[35]	15.1	15.2	15.4	15.5	15.6	15.7
.5	13.7	13.8	14.0	14.1	14.2	14.3		14.5	14.6	14.7	14.8	15.0	15.1		15.2	15.3	15.5	15.6	15.7	15.8
36.0	13.8	13.9	14.0	14.2	14.3	14.4	[36]	14.5	14.7	14.8	14.9	15.0	15.2	[36]	15.3	15.4	15.5	15.7	15.8	15.9
.5	13.9	14.0	14.1	14.3	14.4	14.5		14.6	14.8	14.9	15.0	15.1	15.3		15.4	15.5	15.6	15.8	15.9	16.0
37.0	14.0	14.1	14.2	14.4	14.5	14.6	[37]	14.7	14.9	15.0	15.1	15.2	15.4	[37]	15.5	15.6	15.7	15.9	16.0	16.1
.5	14.1	14.2	14.3	14.4	14.6	14.7		14.8	14.9	15.1	15.2	15.3	15.4		15.6	15.7	15.8	15.9	16.1	16.2
38.0	14.2	14.3	14.4	14.5	14.7	14.8	[38]	14.9	15.0	15.2	15.3	15.4	15.5	[38]	15.7	15.8	15.9	16.0	16.2	16.3
.5	14.3	14.4	14.5	14.6	14.8	14.9		15.0	15.1	15.3	15.4	15.5	15.6		15.8	15.9	16.0	16.1	16.3	16.4
39.0	14.4	14.5	14.6	14.7	14.9	15.0	[39]	15.1	15.2	15.3	15.5	15.6	15.7	[39]	15.8	16.0	16.1	16.2	16.3	16.5
.5	14.4	14.6	14.7	14.8	14.9	15.1		15.2	15.3	15.4	15.6	15.7	15.8		15.9	16.1	16.2	16.3	16.4	16.6
40.0	14.5	14.7	14.8	14.9	15.0	15.2	[40]	15.3	15.4	15.5	15.7	15.8	15.9	[40]	16.0	16.2	16.3	16.4	16.5	16.7
.5	14.6	14.8	14.9	15.0	15.1	15.3		15.4	15.5	15.6	15.8	15.9	16.0		16.1	16.3	16.4	16.5	16.6	16.8
41.0	14.7	14.8	15.0	15.1	15.2	15.3	[41]	15.5	15.6	15.7	15.8	16.0	16.1	[41]	16.2	16.3	16.5	16.6	16.7	16.8
.5	14.8	14.9	15.1	15.2	15.3	15.4		15.6	15.7	15.8	15.9	16.1	16.2		16.3	16.4	16.6	16.7	16.8	16.9
42.0	14.9	15.0	15.2	15.3	15.4	15.5	[42]	15.7	15.8	15.9	16.0	16.2	16.3	[42]	16.4	16.5	16.7	16.8	16.9	17.0
.5	15.0	15.1	15.2	15.4	15.5	15.6		15 7	15.9	16.0	16.1	16.2	16.4		16.5	16.6	16.7	16.9	17.0	17.1
43.0	15.1	15.2	15.3	15.5	15.6	15.7	[43]	15.8	16.0	16.1	16.2	16.3	16.5	[43]	16.6	16.7	16.8	17.0	17.1	17.2
.5	15.2	15.3	15.4	15.6	15.7	15.8		15.9	16.1	16.2	16.3	16.4	16.6		16.7	16.8	16.9	17.1	17.2	17.3
44.0	15.3	15.4	15.5	15.7	15.8	15.9	[44]	16.0	16.2	16.3	16.4	16.5	16.7	[44]	16.8	16.9	17.0	17.2	17.3	17.4
.5	15.4	15.5	15.6	15.7	15.9	16.0		16.1	16.2	16.4	16.5	16.6	16.7		16.9	17.0	17.1	17.2	17.4	17.5
45.0	15.5	15.6	15.7	15.8	16.0	16.1	[45]	16.2	16.3	16.5	16.6	16.7	16.8	[45]	17.0	17.1	17.2	17.3	17.5	17.6
.5	15.6	15.7	15.8	15.9	16.1	16.2		16.3	16.4	16.6	16.7	16.8	16.9		17.1	17.2	17.3	17.4	17.6	17.7
46.0	15.6	15.8	15.9	16 0	16.1	16.3	[46]	16.4	16.5	16.6	16.8	16.9	17.0	[46]	17.2	17.3	17.4	17.5	17.6	17.8
.5	15.7	15.9	16.0	16.1	16.2	16.4		16.5	16.6	16.7	16.9	17.0	17.1		17.2	17.4	17.5	17.6	17.7	17.9
47.0	15.8	16.0	16.1	16.2	16.3	16.5	[47]	16.6	16.7	16.8	17.0	17.1	17.2	[47]	17.3	17.5	17.6	17.7	17.8	18.0
.5	15.9	16.1	16.2	16.3	16.4	16.6		16.7	16.8	16.9	17.1	17.2	17.3		17.4	17.6	17.7	17.8	17.9	18.1
48.0	16.0	16.1	16.3	16.4	16.5	16.6	[48]	16.8	16.9	17.0	17.1	17.3	17.4	[48]	17.5	17.6	17.8	17.9	18.0	18.1
.5	16.1	16.2	16.4	16.5	16.6	16.7		16.9	17.0	17.1	17.2	17.4	17.5		17.6	17.7	17.9	18.0	18.1	18.2
49.0	16.2	16.3	16.5	16.6	16.7	16.8	[49]	17.0	17.1	17.2	17.3	17.5	17.6	[49]	17.7	17.8	18.0	18.1	18.2	18.3
.5	16.3	16.4	16.5	16.7	16.8	16.9		17.0	17.2	17.3	17.4	17.5	17.7		17.8	17.9	18.1	18.2	18.3	18.4
50.0	16.4	16.5	16.6	16.8	16.9	17.0	[50]	17.1	17.3	17.4	17.5	17.6	17.8	[50]	17.9	18.0	18.1	18.3	18.4	18.5
.5	16.5	16.6	16.7	16.9	17.0	17.1		17.2	17.4	17.5	17.6	17.7	17.9		18.0	18.1	18.2	18.4	18.5	18.6
51.0	16.6	16.7	16.8	17.0	17.1	17.2	[51]	17.3	17.5	17.6	17.7	17.8	18.0	[51]	18.1	18.2	18.3	18.5	18.6	18.7
.5	16.7	16.8	16.9	17.0	17.2	17.3		17.4	17.5	17.7	17.8	17.9	18.0		18.2	18.3	18.4	18.5	18.7	18.8
52.0	16.8	16.9	17.0	17.1	17.3	17.4	[52]	17.5	17.6	17.8	17.9	18.0	18.1	[52]	18.3	18.4	18.5	18.6	18.8	18.9
.5	16.9	17.0	17.1	17.2	17.4	17.5		17.6	17.7	17.9	18.0	18.1	18.2		18.4	18.5	18.6	18.7	18.9	19.0

Table V

TO BE USED IN CONJUNCTION WITH TABLE VI AND TABLE VII FOR DETERMINATION OF BICEPS SUBCUTANEOUS TISSUE EXPECTATION FROM SKELETAL MEASURES

(Eleven-Year-Old Boys)

HIPS	HEIGHT																		
	49.0	49.5	50.0	50.5	51.0	51.5		52.0	52.5	53.0	53.5	54.0	54.5		55.0	55.5	56.0	56.5	57.0	57.5
20.00	5.0	4.9	4.8	4.6	4.5	4.4	[20]	4.3	4.2	4.1	3.9	3.8	3.7	[20]	3.6	3.5	3.3	3.2	3.1	3.0
.25	5.2	5.1	5.0	4.9	4.7	4.6		4.5	4.4	4.3	4.1	4.0	3.9		3.8	3.7	3.5	3.4	3.3	3.2
.50	5.4	5.3	5.2	5.1	4.9	4.8		4.7	4.6	4.5	4.3	4.2	4.1		4.0	3.9	3.8	3.6	3.5	3.4
.75	5.6	5.5	5.4	5.3	5.2	5.0		4.9	4.8	4.7	4.6	4.4	4.3		4.2	4.1	4.0	3.8	3.7	3.6
21.00	5.8	5.7	5.6	5.5	5.4	5.2	[21]	5.1	5.0	4.9	4.8	4.6	4.5	[21]	4.4	4.3	4.2	4.1	3.9	3.8
.25	6.0	5.9	5.8	5.7	5.6	5.4		5.3	5.2	5.1	5.0	4.9	4.7		4.6	4.5	4.4	4.3	4.1	4.0
.50	6.2	6.1	6.0	5.9	5.8	5.7		5.5	5.4	5.3	5.2	5.1	4.9		4.8	4.7	4.6	4.5	4.3	4.2
.75	6.5	6.3	6.2	6.1	6.0	5.9		5.7	5.6	5.5	5.4	5.3	5.1		5.0	4.9	4.8	4.7	4.6	4.4
22.00	6.7	6.5	6.4	6.3	6.2	6.1	[22]	6.0	5.8	5.7	5.6	5.5	5.4	[22]	5.2	5.1	5.0	4.9	4.8	4.6
.25	6.9	6.8	6.6	6.5	6.4	6.3		6.2	6.0	5.9	5.8	5.7	5.6		5.4	5.3	5.2	5.1	5.0	4.9
.50	7.1	7.0	6.8	6.7	6.6	6.5		6.4	6.2	6.1	6.0	5.9	5.8		5.7	5.5	5.4	5.3	5.2	5.1
.75	7.3	7.2	7.0	6.9	6.8	6.7		6.6	6.5	6.3	6.2	6.1	6.0		5.9	5.7	5.6	5.5	5.4	5.3
23.00	7.5	7.4	7.3	7.1	7.0	6.9	[23]	6.8	6.7	6.5	6.4	6.3	6.2	[23]	6.1	5.9	5.8	5.7	5.6	5.5
.25	7.7	7.6	7.5	7.3	7.2	7.1		7.0	6.9	6.7	6.6	6.5	6.4		6.3	6.2	6.0	5.9	5.8	5.7
.50	7.9	7.8	7.7	7.6	7.4	7.3		7.2	7.1	7.0	6.8	6.7	6.6		6.5	6.4	6.2	6.1	6.0	5.9
.75	8.1	8.0	7.9	7.8	7.6	7.5		7.4	7.3	7.2	7.0	6.9	6.8		6.7	6.6	6.5	6.3	6.2	6.1
24.00	8.3	8.2	8.1	8.0	7.8	7.7	[24]	7.6	7.5	7.4	7.3	7.1	7.0	[24]	6.9	6.8	6.7	6.5	6.4	6.3
.25	8.5	8.4	8.3	8.2	8.1	7.9		7.8	7.7	7.6	7.5	7.3	7.2		7.1	7.0	6.9	6.7	6.6	6.5
.50	8.7	8.6	8.5	8.4	8.3	8.1		8.0	7.9	7.8	7.7	7.5	7.4		7.3	7.2	7.1	7.0	6.8	6.7
.75	8.9	8.8	8.7	8.6	8.5	8.4		8.2	8.1	8.0	7.9	7.8	7.6		7.5	7.4	7.3	7.2	7.0	6.9
25.00	9.2	9.0	8.9	8.8	8.7	8.6	[25]	8.4	8.3	8.2	8.1	8.0	7.8	[25]	7.7	7.6	7.5	7.4	7.3	7.1
.25	9.4	9.2	9.1	9.0	8.9	8.8		8.6	8.5	8.4	8.3	8.2	8.1		7.9	7.8	7.7	7.6	7.5	7.3
.50	9.6	9.4	9.3	9.2	9.1	9.0		8.9	8.7	8.6	8.5	8.4	8.3		8.1	8.0	7.9	7.8	7.7	7.5
.75	9.8	9.7	9.5	9.4	9.3	9.2		9.1	8.9	8.8	8.7	8.6	8.5		8.3	8.2	8.1	8.0	7.9	7.8
26.00	10.0	9.9	9.7	9.6	9.5	9.4	[26]	9.3	9.2	9.0	8.9	8.8	8.7	[26]	8.6	8.4	8.3	8.2	8.1	8.0
.25	10.2	10.1	10.0	9.8	9.7	9.6		9.5	9.4	9.2	9.1	9.0	8.9		8.8	8.6	8.5	8.4	8.3	8.2
.50	10.4	10.3	10.2	10.0	9.9	9.8		9.7	9.6	9.4	9.3	9.2	9.1		9.0	8.9	8.7	8.6	8.5	8.4
.75	10.6	10.5	10.4	10.2	10.1	10.0		9.9	9.8	9.7	9.5	9.4	9.3		9.2	9.1	8.9	8.8	8.7	8.6
27.00	10.8	10.7	10.6	10.5	10.3	10.2	[27]	10.1	10.0	9.9	9.7	9.6	9.5	[27]	9.4	9.3	9.1	9.0	8.9	8.8
.25	11.0	10.9	10.8	10.7	10.5	10.4		10.3	10.2	10.1	10.0	9.8	9.7		9.6	9.5	9.4	9.2	9.1	9.0
.50	11.2	11.1	11.0	10.9	10.8	10.6		10.5	10.4	10.3	10.2	10.0	9.9		9.8	9.7	9.6	9.4	9.3	9.2
.75	11.4	11.3	11.2	11.1	11.0	10.8		10.7	10.6	10.5	10.4	10.2	10.1		10.0	9.9	9.8	9.7	9.5	9.4
28.00	11.6	11.5	11.4	11.3	11.2	11.0	[28]	10.9	10.8	10.7	10.6	10.5	10.3	[28]	10.2	10.1	10.0	9.9	9.7	9.6
.25	11.8	11.7	11.6	11.5	11.4	11.3		11.1	11.0	10.9	10.8	10.7	10.5		10.4	10.3	10.2	10.1	9.9	9.8
.50	12.1	11.9	11.8	11.7	11.6	11.5		11.3	11.2	11.1	11.0	10.9	10.8		10.6	10.5	10.4	10.3	10.2	10.0
.75	12.3	12.1	12.0	11.9	11.8	11.7		11.6	11.4	11.3	11.2	11.1	11.0		10.8	10.7	10.6	10.5	10.4	10.2
29.00	12.5	12.4	12.2	12.1	12.0	11.9	[29]	11.8	11.6	11.5	11.4	11.3	11.2	[29]	11.0	10.9	10.8	10.7	10.6	10.5
.25	12.7	12.6	12.4	12.3	12.2	12.1		12.0	11.8	11.7	11.6	11.5	11.4		11.3	11.1	11.0	10.9	10.8	10.7
.50	12.9	12.8	12.6	12.5	12.4	12.3		12.2	12.1	11.9	11.8	11.7	11.6		11.5	11.3	11.2	11.1	11.0	10.9
.75	13.1	13.0	12.9	12.7	12.6	12.5		12.4	12.3	12.1	12.0	11.9	11.8		11.7	11.5	11.4	11.3	11.2	11.1
30.00	13.3	13.2	13.1	12.9	12.8	12.7	[30]	12.6	12.5	12.4	12.2	12.1	12.0	[30]	11.9	11.8	11.6	11.5	11.4	11.3
.25	13.5	13.4	13.3	13.2	13.0	13.0		12.8	12.7	12.6	12.4	12.3	12.2		12.1	12.0	11.8	11.7	11.6	11.5
.50	13.7	13.6	13.5	13.4	13.2	13.1		13.0	12.9	12.8	12.6	12.5	12.4		12.3	12.2	12.1	11.9	11.8	11.7
.75	13.9	13.8	13.7	13.6	13.4	13.3		13.2	13.1	13.0	12.9	12.7	12.6		12.5	12.4	12.3	12.1	12.0	11.9

Continued on next page

Table V—(Continued)

TO BE USED IN CONJUNCTION WITH TABLE VI AND TABLE VII FOR DETERMINATION OF BICEPS SUBCUTANEOUS TISSUE EXPECTATION FROM SKELETAL MEASURES

(Eleven-Year-Old Boys)

HIPS	HEIGHT																		
	58.0	58.5	59.0	59.5	60.0	60.5		61.0	61.5	62.0	62.5	63.0	63.5		64.0	64.5	65.0	65.5	66.0	66.5
20.00	2.9	2.7	2.6	2.5	2.4	2.3	[20]	2.2	2.0	1.9	1.8	1.7	1.6	[20]	1.4	1.3	1.2	1.1	1.0	.8
.25	3.1	3.0	2.8	2.7	2.6	2.5		2.4	2.2	2.1	2.0	1.9	1.8		1.6	1.5	1.4	1.3	1.2	1.1
.50	3.3	3.2	3.0	2.9	2.8	2.7		2.6	2.4	2.3	2.2	2.1	2.0		1.9	1.7	1.6	1.5	1.4	1.3
.75	3.5	3.4	3.3	3.1	3.0	2.9		2.8	2.7	2.5	2.4	2.3	2.2		2.1	1.9	1.8	1.7	1.6	1.5
21.00	3.7	3.6	3.5	3.3	3.2	3.1	[21]	3.0	2.9	2.7	2.6	2.5	2.4	[21]	2.3	2.2	2.0	1.9	1.8	1.7
.25	3.9	3.8	3.7	3.5	3.4	3.3		3.2	3.1	3.0	2.8	2.7	2.6		2.5	2.4	2.2	2.1	2.0	1.9
.50	4.1	4.0	3.9	3.8	3.6	3.5		3.4	3.3	3.2	3.0	2.9	2.8		2.7	2.6	2.4	2.3	2.2	2.1
.75	4.3	4.2	4.1	4.0	3.8	3.7		3.6	3.5	3.4	3.2	3.1	3.0		2.9	2.8	2.7	2.5	2.4	2.3
22.00	4.5	4.4	4.3	4.2	4.0	3.9	[22]	3.8	3.7	3.6	3.5	3.3	3.2	[22]	3.1	3.0	2.9	2.7	2.6	2.5
.25	4.7	4.6	4.5	4.4	4.3	4.1		4.0	3.9	3.8	3.7	3.5	3.4		3.3	3.2	3.1	3.0	2.8	2.7
.50	4.9	4.8	4.7	4.6	4.5	4.3		4.2	4.1	4.0	3.9	3.8	3.6		3.5	3.4	3.3	3.2	3.0	2.9
.75	5.1	5.0	4.9	4.8	4.7	4.6		4.4	4.3	4.2	4.1	4.0	3.8		3.7	3.6	3.5	3.4	3.2	3.1
23.00	5.4	5.2	5.1	5.0	4.9	4.8	[23]	4.6	4.5	4.4	4.3	4.2	4.0	[23]	3.9	3.8	3.7	3.6	3.5	3.3
.25	5.6	5.4	5.3	5.2	5.1	5.0		4.8	4.7	4.6	4.5	4.4	4.3		4.1	4.0	3.9	3.8	3.7	3.5
.50	5.8	5.7	5.4	5.4	5.3	5.2		5.1	4.9	4.8	4.7	4.6	4.5		4.3	4.2	4.1	4.0	3.9	3.8
.75	6.0	5.9	5.7	5.6	5.5	5.4		5.3	5.1	5.0	4.9	4.8	4.7		4.6	4.4	4.3	4.2	4.1	4.0
24.00	6.2	6.1	5.9	5.8	5.7	5.6	[24]	5.5	5.4	5.2	5.1	5.0	4.9	[24]	4.8	4.6	4.5	4.4	4.3	4.2
.25	6.4	6.3	6.2	6.0	5.9	5.8		5.7	5.6	5.4	5.3	5.2	5.1		5.0	4.8	4.7	4.6	4.5	4.4
.50	6.6	6.5	6.4	6.2	6.1	6.0		5.9	5.8	5.6	5.5	5.4	5.3		5.2	5.1	4.9	4.8	4.7	4.6
.75	6.8	6.7	6.6	6.5	6.3	6.2		6.1	6.0	5.9	5.7	5.6	5.5		5.4	5.3	5.1	5.0	4.9	4.8
25.00	7.0	6.9	6.8	6.7	6.5	6.4	[25]	6.3	6.2	6.1	5.9	5.8	5.7	[25]	5.6	5.5	5.4	5.2	5.1	5.0
.25	7.2	7.1	7.0	6.9	6.7	6.6		6.5	6.4	6.3	6.2	6.0	5.9		5.8	5.7	5.6	5.4	5.3	5.2
.50	7.4	7.3	7.2	7.1	7.0	6.8		6.7	6.6	6.5	6.4	6.2	6.1		6.0	5.9	5.8	5.6	5.5	5.4
.75	7.6	7.5	7.4	7.3	7.2	7.0		6.9	6.8	6.7	6.6	6.4	6.3		6.2	6.1	6.0	5.9	5.7	5.6
26.00	7.8	7.7	7.6	7.5	7.4	7.3	[26]	7.1	7.0	6.9	6.8	6.7	6.5	[26]	6.4	6.3	6.2	6.1	5.9	5.8
.25	8.1	7.9	7.8	7.7	7.6	7.5		7.3	7.2	7.1	7.0	6.9	6.7		6.6	6.5	6.4	6.3	6.2	6.0
.50	8.3	8.1	8.0	7.9	7.8	7.7		7.5	7.4	7.3	7.2	7.1	7.0		6.8	6.7	6.6	6.5	6.4	6.2
.75	8.5	8.3	8.2	8.1	8.0	7.9		7.8	7.6	7.5	7.4	7.3	7.2		7.0	6.9	6.8	6.7	6.6	6.4
27.00	8.7	8.6	8.4	8.3	8.2	8.1	[27]	8.0	7.8	7.7	7.6	7.5	7.4	[27]	7.2	7.1	7.0	6.9	6.8	6.7
.25	8.9	8.8	8.6	8.5	8.4	8.3		8.2	8.1	7.9	7.8	7.7	7.6		7.5	7.3	7.2	7.1	7.0	6.9
.50	9.1	9.0	8.9	8.7	8.6	8.5		8.4	8.3	8.1	8.0	7.9	7.8		7.7	7.5	7.4	7.3	7.2	7.1
.75	9.3	9.2	9.1	8.9	8.8	8.7		8.6	8.5	8.3	8.2	8.1	8.0		7.9	7.8	7.6	7.5	7.4	7.3
28.00	9.5	9.4	9.3	9.1	9.0	8.9	[28]	8.8	8.7	8.6	8.4	8.3	8.2	[28]	8.1	8.0	7.8	7.7	7.6	7.5
.25	9.7	9.6	9.5	9.4	9.2	9.1		9.0	8.9	8.8	8.6	8.5	8.4		8.3	8.2	8.0	7.9	7.8	7.7
.50	9.9	9.8	9.7	9.6	9.4	9.3		9.2	9.1	9.0	8.9	8.7	8.6		8.5	8.4	8.3	8.1	8.0	7.9
.75	10.1	10.0	9.9	9.8	9.6	9.5		9.4	9.3	9.2	9.1	8.9	8.8		8.7	8.6	8.5	8.3	8.2	8.1
29.00	10.3	10.2	10.1	10.0	9.9	9.7	[29]	9.6	9.5	9.4	9.3	9.1	9.0	[29]	8.9	8.8	8.7	8.6	8.4	8.3
.25	10.5	10.4	10.3	10.2	10.1	9.9		9.8	9.7	9.6	9.5	9.4	9.2		9.1	9.0	8.9	8.8	8.6	8.5
.50	10.7	10.6	10.5	10.4	10.3	10.2		10.0	9.9	9.8	9.7	9.6	9.4		9.3	9.2	9.1	9.0	8.8	8.7
.75	11.0	10.8	10.7	10.6	10.5	10.4		10.2	10.1	10.0	9.9	9.8	9.6		9.5	9.4	9.3	9.2	9.1	8.9
30.00	11.2	11.0	10.9	10.8	10.7	10.6	[30]	10.5	10.3	10.2	10.1	10.0	9.9	[30]	9.7	9.6	9.5	9.4	9.3	9.1
.25	11.4	11.3	11.1	11.0	10.9	10.8		10.7	10.5	10.4	10.3	10.2	10.1		9.9	9.8	9.7	9.6	9.5	9.4
.50	11.6	11.5	11.3	11.2	11.1	11.0		10.9	10.7	10.6	10.5	10.4	10.3		10.2	10.0	9.9	9.8	9.7	9.6
.75	11.8	11.7	11.5	11.4	11.3	11.2		11.1	11.0	10.8	10.7	10.6	10.5		10.4	10.2	10.1	10.0	9.9	9.8

Table VI

TO BE USED IN CONJUNCTION WITH TABLE V AND TABLE VII FOR DETERMINATION OF BICEPS SUBCUTANEOUS TISSUE EXPECTATION FROM SKELETAL MEASURES

(Eleven-Year-Old Boys)

CHEST BREADTH	CHEST DEPTH																		
	24.0	24.5	25.0	25.5	26.0	26.5		27.0	27.5	28.0	28.5	29.0	29.5		30.0	30.5	31.0	31.5	32.0	32.5
35.0	18.1	18.4	18.7	19.0	19.2	19.5	[35]	19.8	20.1	20.4	20.7	21.0	21.3	[35]	21.6	21.9	22.2	22.5	22.8	23.0
.5	18.3	18.6	18.9	19.2	19.5	19.8		20.1	20.4	20.7	21.0	21.2	21.5		21.8	22.1	22.4	22.7	23.0	23.3
36.0	18.6	18.9	19.2	19.4	19.7	20.0	[36]	20.3	20.6	20.9	21.2	21.5	21.8	[36]	22.1	22.4	22.7	23.0	23.2	23.5
.5	18.8	19.1	19.4	19.7	20.0	20.3		20.6	20.9	21.2	21.5	21.7	22.0		22.3	22.6	22.9	23.2	23.5	23.8
37.0	19.1	19.4	19.7	19.9	20.2	20.5	[37]	20.8	21.1	21.4	21.7	22.0	22.3	[37]	22.6	22.9	23.2	23.5	23.7	24.0
.5	19.3	19.6	19.9	20.2	20.5	20.8		21.1	21.4	21.7	21.9	22.2	22.5		22.8	23.1	23.4	23.7	24.0	24.3
38.0	19.6	19.9	20.1	20.4	20.7	21.0	[38]	21.3	21.6	21.9	22.2	22.5	22.8	[38]	23.1	23.4	23.7	23.9	24.2	24.5
.5	19.8	20.1	20.4	20.7	21.0	21.3		21.6	21.9	22.1	22.4	22.7	23.0		23.3	23.6	23.9	24.2	24.5	24.8
39.0	20.1	20.4	20.6	20.9	21.2	21.5	[39]	21.8	22.1	22.4	22.7	23.0	23.3	[39]	23.6	23.9	24.2	24.4	24.7	25.0
.5	20.3	20.6	20.9	21.2	21.5	21.8		22.1	22.4	22.6	22.9	23.2	23.5		23.8	24.1	24.4	24.7	25.0	25.3
40.0	20.6	20.8	21.1	21.4	21.7	22.0	[40]	22.3	22.6	22.9	23.2	23.5	23.8	[40]	24.1	24.4	24.6	24.9	25.2	25.5
.5	20.8	21.1	21.4	21.7	22.0	22.3		22.6	22.8	23.1	23.4	23.7	24.0		24.3	24.6	24.9	25.1	25.5	25.8
41.0	21.0	21.3	21.6	21.9	22.2	22.5	[41]	22.8	23.1	23.4	23.7	24.0	24.3	[41]	24.6	24.8	25.1	25.4	25.7	26.0
.5	21.3	21.6	21.9	22.2	22.5	22.8		23.1	23.3	23.6	23.9	24.2	24.5		24.8	25.1	25.4	25.7	26.0	26.3
42.0	21.5	21.8	22.1	22.4	22.7	23.0	[42]	23.3	23.6	23.9	24.2	24.5	24.8	[42]	25.1	25.3	25.6	25.9	26.2	26.5
.5	21.8	22.1	22.4	22.7	23.0	23.3		23.5	23.8	24.1	24.4	24.7	25.0		25.3	25.6	25.9	26.2	26.5	26.8
43.0	22.0	22.3	22.6	22.9	23.2	23.5	[43]	23.8	24.1	24.4	24.7	25.0	25.3	[43]	25.5	25.8	26.1	26.4	26.7	27.0
.5	22.3	22.6	22.9	23.2	23.5	23.7		24.0	24.3	24.6	24.9	25.2	25.5		25.8	26.1	26.4	26.7	27.0	27.3
44.0	22.5	22.8	23.1	23.4	23.7	24.0	[44]	24.3	24.6	24.9	25.2	25.5	25.8	[44]	26.0	26.3	26.6	26.9	27.2	27.5
.5	22.8	23.1	23.4	23.7	24.0	24.2		24.5	24.8	25.1	25.4	25.7	26.0		26.3	26.6	26.9	27.2	27.5	27.8
45.0	23.0	23.3	23.6	23.9	24.2	24.5	[45]	24.8	25.1	25.4	25.7	26.0	26.2	[45]	26.5	26.8	27.1	27.4	27.7	28.0
.5	23.3	23.6	23.9	24.2	24.4	24.7		25.0	25.3	25.6	25.9	26.2	26.5		26.8	27.1	27.4	27.7	28.0	28.2
46.0	23.5	23.8	24.1	24.4	24.7	25.0	[46]	25.3	25.6	25.9	26.2	26.4	26.7	[46]	27.0	27.3	27.6	27.9	28.2	28.5
.5	23.8	24.1	24.4	24.7	24.9	25.2		25.5	25.8	26.1	26.4	26.7	27.0		27.3	27.6	27.9	28.2	28.5	28.7
47.0	24.0	24.3	24.6	24.9	25.2	25.5	[47]	25.8	26.1	26.4	26.7	26.9	27.2	[47]	27.5	27.8	28.1	28.4	28.7	29.0
.5	24.3	24.6	24.9	25.1	25.4	25.7		26.0	26.3	26.6	26.9	27.2	27.5		27.8	28.1	28.4	28.7	28.9	29.2
48.0	24.5	24.8	25.1	15.4	25.7	26.0	[48]	26.3	26.6	26.9	27.1	27.4	27.7	[48]	28.0	28.3	28.6	28.9	29.2	29.5
.5	24.8	25.1	25.3	25.6	25.9	26.2		26.5	26.8	27.1	27.4	27.7	28.0		28.3	28.6	28.9	29.1	29.4	29.7
49.0	25.0	25.3	25.6	25.9	26.2	26.5	[49]	26.8	27.1	27.4	27.6	27.9	28.2	[49]	28.5	28.8	29.1	29.4	29.7	30.0
.5	25.3	25.6	25.8	26.1	26.4	26.7		27.0	27.3	27.6	27.9	28.2	28.5		28.8	29.1	29.4	29.6	29.9	30.2
50.0	25.5	25.8	26.1	26.4	26.7	27.0	[50]	27.3	27.6	27.8	28.1	28.4	28.7	[50]	29.0	29.3	29.6	29.9	30.2	30.5
.5	25.8	26.0	26.3	26.6	26.9	27.2		27.5	27.8	28.1	28.4	28.7	29.0		29.3	29.6	29.8	30.1	30.4	30.7
51.0	26.0	26.3	26.6	26.9	27.2	27.5	[51]	27.8	28.0	28.3	28.6	28.9	29.2	[51]	29.5	29.8	30.1	30.4	30.7	31.0
.5	26.3	26.5	26.8	27.1	27.4	27.7		28.0	28.3	28.6	28.9	29.2	29.5		29.8	30.1	30.3	30.6	30.9	31.2
52.0	26.5	26.8	27.1	27.4	27.7	28.0	[52]	28.3	28.5	28.8	29.1	29.4	29.7	[52]	30.0	30.3	30.6	30.9	31.2	31.5
.5	26.7	27.0	27.3	27.6	27.9	28.2		28.5	28.8	29.1	29.4	29.7	30.0		30.3	30.5	30.8	31.1	31.4	31.7

Continued on next page

Table VI—Continued

TO BE USED IN CONJUNCTION WITH TABLE V AND TABLE VII FOR DETERMINATION OF BICEPS SUBCUTANEOUS TISSUE EXPECTATION FROM SKELETAL MEASURES

(Eleven-Year-Old Boys)

CHEST BREADTH	CHEST DEPTH																		
	33.0	33.5	34.0	34.5	35.0	35.5		36.0	36.5	37.0	37.5	38.0	38.5		39.0	39.5	40.0	40.5	41.0	41.5
35.0	23.3	23.6	23.9	24.2	24.5	24.8	[35]	25.1	25.4	25.7	26.0	26.3	26.6	[35]	26.8	27.1	27.4	27.7	28.0	28.3
.5	23.6	23.9	24.2	24.5	24.8	25.0		25.3	25.6	25.9	26.2	26.5	26.8		27.1	27.4	27.7	28.0	28.3	28.6
36.0	23.8	24.1	24.4	24.7	25.0	25.3	[36]	25.6	25.9	26.2	26.5	26.8	27.0	[36]	27.3	27.6	27.9	28.2	28.5	28.8
.5	24.1	24.4	24.7	25.0	25.3	25.5		25.8	26.1	26.4	26.7	27.0	27.3		27.6	27.9	28.2	28.5	28.8	29.0
37.0	24.3	24.6	24.9	25.2	25.5	25.8	[37]	26.1	26.4	26.7	27.0	27.3	27.5	[37]	27.8	28.1	28.4	28.7	29.0	29.3
.5	24.6	24.9	25.2	25.5	25.7	26.0		26.3	26.6	26.9	27.2	27.5	27.8		28.1	28.4	28.7	29.0	29.3	29.5
38.0	24.8	25.1	25.4	25.7	26.0	26.3	[38]	26.6	26.9	27.2	27.5	27.7	28.0	[38]	28.3	28.6	28.9	29.2	29.5	29.8
.5	25.1	25.4	25.7	25.9	26.2	26.5		26.8	27.1	27.4	27.7	28.0	28.3		28.6	28.9	29.2	29.5	29.7	30.0
39.0	25.3	25.6	25.9	26.2	26.5	26.8	[39]	27.1	27.4	27.7	28.0	28.2	28.5	[39]	28.8	29.1	29.4	29.7	30.0	30.3
.5	25.6	25.9	26.2	26.4	26.7	27.0		27.3	27.6	27.9	28.2	28.5	28.8		29.1	29.4	29.7	30.0	30.2	30.5
40.0	25.8	26.1	26.4	26.7	27.0	27.3	[40]	27.6	27.9	28.2	28.4	28.7	29.0	[40]	29.3	29.6	29.9	30.2	30.5	30.8
.5	26.1	26.4	26.6	26.9	27.2	27.5		27.8	28.1	28.4	28.7	29.0	29.3		29.6	29.9	30.2	30.4	30 7	31.0
41.0	26.3	26.6	26.9	27.2	27.5	27.8	[41]	28.1	28.4	28.6	28.9	29.2	29.5	[41]	29.8	30.1	30.4	30.7	31.0	31.3
.5	26.6	26.9	27.1	27.4	27.7	28.0		28.3	28.6	28.9	29.2	29.5	29.8		30.1	30.4	30.6	30.9	31.2	31.5
42.0	26.8	27.1	27.4	27.7	28.0	28.3	[42]	28.6	28.9	29.1	29.4	29.7	30.0	[42]	30.3	30.6	30.9	31.2	31.5	31.8
.5	27.1	27.3	27.6	27.9	28.2	28.5		28.8	29.1	29.4	29.7	30.0	30.3		30.6	30.9	31.1	31.4	31.7	32.0
43.0	27.3	27.6	27.9	28.2	28.5	28.8	[43]	29.1	29.3	29.6	29.9	30.2	30.5	[43]	30.8	31.1	31.4	31.7	32.0	32.3
.5	27.5	27.8	28.1	28.4	28.7	29.0		29.3	29.6	29.9	30.2	20.5	30.8		31.1	31.3	31.6	31.9	32.2	32.5
44.0	27.8	28.1	28.4	28.7	29.0	29.3	[44]	29.6	29.8	30.1	30.4	30.7	31.0	[44]	31.3	31.6	31.9	32.2	32.5	32.8
.5	28.0	28.3	28.6	28.9	29.2	29.5		29.8	30.1	30.4	30.7	31.0	31.3		31.6	31.8	32.1	32.4	32.7	33.0
45.0	28.3	28.6	28.9	29.2	29.5	29.8	[45]	30.0	30.3	30.6	30.9	31.2	31.5	[45]	31.8	32.1	32.4	32.7	33.0	33.3
.5	28.5	28.8	29.1	29.4	29.7	30.0		30.3	30.6	30.9	31.2	31.5	31.8		32.0	32.3	32.6	32.9	33.2	33.5
46.0	28.8	29.1	29.4	29.7	30.0	30.2	[46]	30.5	30.8	31.1	31.4	31.7	32.0	[46]	32.3	32.6	32.9	33.2	33.5	33.8
.5	29.0	29.3	29.6	29.9	30.2	30.5		30.8	31.1	31.4	31.7	32.0	32.2		32.5	32.8	33.1	33.4	33.7	34.0
47.0	29.3	29.6	29.9	30.2	30.5	30.7	[47]	31.0	31.3	31.6	31.9	32.2	32.5	[47]	32.8	33.1	33.4	33.7	34.0	34.3
.5	29.5	29.8	30.1	30.4	30.7	31.0		31.3	31.6	31.9	32.2	32.5	32.7		33.0	33.3	33.6	33.9	34.2	34.5
48.0	29.8	30.1	30.4	30.7	30.9	31.2	[48]	31.5	31.8	32.1	32.4	32.7	33.0	[48]	33.3	33.6	33.9	34.2	34.5	34.7
.5	30 0	30.3	30.6	30.9	31.2	31.5		31.8	32.1	32.4	32.7	32.9	33.2		33.5	33.8	34.1	34.4	34.7	35.0
49.0	30.3	30.6	30.9	31.2	31.4	31.7	[49]	32.0	32.3	32.6	32.9	33.2	33.5	[49]	33.8	34.1	34.4	34.7	34.9	35.2
.5	30.5	30.8	31.1	31.4	31.7	32.0		32.3	32.6	32.9	33.2	33.4	33.7		34.0	34.3	34.6	34.9	35.2	35.5
50.0	30.8	31.1	31.4	31.6	31.9	32.2	[50]	32.5	32.8	33.1	33.4	33.7	34.0	[50]	34.3	34.6	34.9	35.2	35.4	35.7
.5	31.0	31.3	31.6	31.9	32.2	32.5		32.8	33.1	33.4	33.6	33.9	34.2		34.5	34.8	35.1	35.4	35.7	36.0
51.0	31.3	31.6	31.8	32.1	32.4	32.7	[51]	33.0	33.3	33.6	33.9	34.2	34.5	[51]	34.8	35.1	35.4	35.6	35.9	36.2
.5	31.5	31.8	32.1	32.4	32.7	33.0		33.3	33.6	33.8	34.1	34.4	34.7		35.0	35.3	35.6	35.9	36.2	36.5
52.0	31.8	32.1	32.3	32.6	32.9	33.2	[52]	33.5	33.8	34.1	34.4	34.7	35.0	[52]	35.3	35.6	35.9	36.1	36.4	36.7
.5	32.0	32.3	32.6	32.9	33.2	33.5		33.8	34.1	34.3	34.6	34.9	35.2		35.5	35.8	36.1	36.4	36.7	37.0

Table VII

TO BE USED IN CONJUNCTION WITH TABLES V AND VI FOR DETERMINATION OF BICEPS SUBCUTANEOUS TISSUE EXPECTATION FROM SKELETAL MEASURES

(Eleven-Year-Old Boys)

Bisacromial Width Measurements	Readings	Bisacromial Width Measurements	Readings
25.0	7.0	31.0	8.7
.5	7.2	.5	8.8
26.0	7.3	32.0	9.0
.5	7.4	.5	9.1
27.0	7.6	33.0	9.2
.5	7.7	.5	9.4
28.0	7.9	34.0	9.5
.5	8.0	.5	9.7
29.0	8.1	35.0	9.8
.5	8.3	.5	9.9
30.0	8.4	36.0	10.1
.5	8.6	.5	10.3

NOTE: These readings must be subtracted from the sum of the readings made from Tables V and VI.

Table VIII

NUMBER OF CHILDREN IN 1000 WHO HAVE *ARM GIRTH* RESIDUALS LESS THAN ANY GIVEN RESIDUAL

(Eleven-Year-Old Boys)

Residual	Number in 1000	Residual	Number in 1000
7.2	999	—.3	449
6.9	998	—.6	401
6.6	997	—.9	352
6.3	996	—1.2	306
6.0	994	—1.5	262
5.7	992	—1.8	224
5.4	989	—2.1	187
5.1	985	—2.4	154
4.8	979	—2.7	127
4.5	971	—3.0	102
4.2	962	—3.3	81
3.9	951	—3.6	64
3.6	936	—3.9	49
3.3	919	—4.2	38
3.0	898	—4.5	29
2.7	873	—4.8	21
2.4	846	—5.1	15
2.1	813	—5.4	11
1.8	776	—5.7	8
1.5	738	—6.0	6
1.2	694	—6.3	4
.9	648	—6.6	3
.6	599	—6.9	2
.3	551	—7.2	1
.0	500		

Table IX

NUMBER OF CHILDREN IN 1000 HAVING *CALF GIRTH* RESIDUALS LESS THAN ANY GIVEN RESIDUAL

(Eleven-Year-Old Boys)

Residual	Number in 1000	Residual	Number in 1000
4.0	999	—.2	440
3.8	998	—.4	383
3.6	996	—.6	327
3.4	994	—.8	275
3.2	991	—1.0	228
3.0	987	—1.2	186
2.8	981	—1.4	149
2.6	974	—1.6	117
2.4	963	—1.8	90
2.2	949	—2.0	68
2.0	932	—2.2	51
1.8	910	—2.4	37
1.6	883	—2.6	26
1.4	851	—2.8	19
1.2	814	—3.0	13
1.0	772	—3.2	9
.8	725	—3.4	6
.6	673	—3.6	4
.4	617	—3.8	2
.2	560	—4.0	1
.0	500		

Table X

NUMBER OF CHILDREN IN 1000 WHO HAVE *BICEPS SUBCUTANEOUS TISSUE* RESIDUALS LESS THAN ANY GIVEN RESIDUAL

(Eleven-Year-Old Boys)

Residual	Number in 1000	Residual	Number in 1000
11.0	999	—.5	445
10.5	998	—1.0	394
10.0	997	—1.5	341
9.5	995	—2.0	292
9.0	993	—2.5	246
8.5	990	—3.0	206
8.0	986	—3.5	169
7.5	980	—4.0	136
7.0	972	—4.5	109
6.5	962	—5.0	85
6.0	949	—5.5	66
5.5	934	—6.0	51
5.0	915	—6.5	38
4.5	891	—7.0	28
4.0	864	—7.5	20
3.5	831	—8.0	14
3.0	794	—8.5	10
2.5	754	—9.0	7
2.0	708	—9.5	5
1.5	659	—10.0	3
1.0	606	—10.5	2
.5	555	—11.0	1
.0	500		

Appendix A

TECHNIQUE FOLLOWED IN OBTAINING PHYSICAL MEASUREMENTS

Appendix A

TECHNIQUE FOLLOWED IN OBTAINING PHYSICAL MEASUREMENTS *

The technique used for the measurements in this monograph is unique in several ways and, therefore, needs description. The objectivity of each measurement is indicated by the coefficients presented in Table 7. Further evidence of the accuracy of the measurements is shown by the high degree of correspondence in the relationships when the correlations were figured separately with twenty different sets of data (see Tables 7 and 8).

The high degree of accuracy obtained by our technicians was acquired after a few days of practice and experience in handling the instruments. The location of the points for measurement was determined by following very precise directions in a careful manner. All the measurements are simple and generally familiar to any one who has experience in making physical measurements. The use of subcutaneous tissue calipers is less familiar in this country but the necessary accuracy in the technique used by us is attained after a brief period of practice.

Our own Fairbanks' scales, transported from place to place, were used in gathering the weight data. The record was made in pounds.

Height was taken with the stadiometers attached to the scales, which were calibrated in inches.

The other skeletal measurements of breadth and depth were made in metric units with the large sliding wooden caliper sold by the Narragansett Machine Company, Providence, R. I. (See caliper at left of Frontispiece.) † The methods used have been adapted from those described by Dr. A. Hrdlicka. Modifications of the directions were made after considerable experience with two or more observers measuring the same children and with definite checks upon accuracy by calculation of coefficients of objectivity.

The deltoid measurements were made with a small standard metal caliper manufactured for the use of machinists. (See caliper in upper right

* A more detailed manual of directions will be prepared later if there is sufficient demand for it.

† The size of this caliper is larger relative to the other three instruments than indicated in the illustration.

SCORE CARD FOR ANTHROPOMETRIC MEASURES

Name..... Examiner..... Sex.....

Age..... School..... Date.....

	HEIGHT		.....
	WEIGHT		.....
WIDTH OF SHOULDERS	Bisacromial		.....
BREADTH OF CHEST	Expiration		.....
	Inspiration		
DEPTH OF CHEST	Expiration		.....
	Inspiration		
HIPS	Width		.....
GIRTH MEASURES	Deltoid	1.	.....
		2.	
		3.	
		4.	
	Upper Arm Flexed	.....	.....
	Upper Arm Relaxed	.....	
	Calf		.....
AMOUNT OF SUBCUTANEOUS TISSUE	Calf	1.	.....
		2.	
		3.	
		4.	
	Biceps	1.	.....
		2.	
	Triceps	1.	.....
		2.	
		3.	
		4.	

hand corner of Frontispiece.) This is an imported instrument sold by Hammacher Schlemmer & Company, New York. The caliper was adapted for our use by attaching a spring to provide a constant pressure against the skin and muscle in each case. The method used in this measurement was developed to indicate the relative size of the deltoid muscle. We have made no arrangements for the manufacture of this modified instrument, because we found that it added no significant information for practical use.

The girth measurements were made with an ordinary steel metric tape rolled in a spring coil case with a Gulick spring handle attachment. (See tape at bottom of Frontispiece.) The tension of the spring in the Gulick handle is balanced against the spring in the coil of the instrument. The measurements were made with the tape snugly around the arm or leg pulling both ends of the tape with the springs so that the wire emerging from the

Gulick handle came out to the "mark" which is placed to indicate the balanced tension against the spring of the coil of the instrument. This method provides for a constant pressure against the tissues of the arm and leg.

The subcutaneous tissue measurements were made with a special caliper devised by the staff of the School Health Study. (See figure in Frontispiece above the tape.) The several types of subcutaneous tissue calipers used by German workers were found to be difficult to use and none of those that we were able to obtain or found described in the literature provided for a constant spring pressure against the skin. The constant spring aids in the ease of manipulation of the instrument and increases the accuracy of the measurements.

INSTRUCTIONS FOLLOWED BY OUR TECHNICIANS

Ask the child to remove coat, sweater, and shoes and empty his pockets.

A. Weight

Be sure scales balance at each half day session before starting measurements.

Weigh and record to the nearest quarter of a pound.

After recording, look again to check record.

B. Skeletal Measurements

I. *Height* *

The child stands on scales with back toward rod, feet together, and heels at edge of platform. Do not let the child lean against the vertical rod. The arms are pendent, the palms turned inward. Have child stand straight with chin level. Do not allow him to stretch up to be taller.

Lower and raise head bar three times before reading height. Record to nearest quarter inch.

The remaining skeletal measurements are taken with the large sliding wooden calipers. Hold the stationary arm in the left hand, the sliding arm in the right, with the arms pointing away from the examiner. Measurements are taken through clothing and recorded to the nearest tenth of a centimeter.

II. *Shoulder Breadth* (Bisacromial diameter)

The subject stands with arms at side as with standing height. Require child to assume neutral position of shoulders, i.e., avoid rounding forward of shoulders or forcing shoulders back. Stand in front of the child.

* Use stadiometer attached to scales. In the absence of accurate stadiometer with scales, the square and scale described by Baldwin, "Physical Growth of Children," is recommended.

Locate acromion processes * with middle fingers while holding calipers in hand, then press arms of calipers snugly against the outer edge of the acromion process. Holding the body of calipers lifted about 45° to a line parallel with the floor to avoid including the shoulder muscles in the measurement, measure and record.

III. *Chest Breadth* (Transverse diameter. Two measurements)

Standing in front of the child, fit calipers under the arms at right angles to the long line of the chest (not to long line of body). On natural breathing take reading for expiration and inspiration with calipers pressed snugly against the chest. To divert the child's attention and to prevent his taking a deep breath or holding the chest rigid, talk to him about any subject of interest. The two measurements, expiration and inspiration, are added to give the chest breadth measures used in this study.†

IV. *Chest Depth* (Antero posterior diameter. Two measurements)

Standing to the left of the child, fit the right arm of the calipers just below the angle of the left scapula and the body of the calipers at right angles to the long line of the chest. The left arm of the calipers falls into position at about the nipple line when the right is properly placed.

With calipers pressed snugly against the chest, record readings for expiration and inspiration on natural breathing. As above, the two measurements are added to give the chest depth measure.†

V. *Hip Breadth* (Bi-trochanteric diameter)

Facing the child, locate the major trochanters by palpation.

Fitting the calipers closely enough to insure bony resistance, record the measurement at the most lateral points.

C. Girth Measurements

I. *Deltoid* ‡ (Four measurements)

Measurements taken with small sliding metal calipers with constant spring. Hold the sliding arm of calipers in the right hand.

* The acromion processes may be readily located by tracing along the spines of the scapulæ and by following the shaft of the clavicle outward. The finger placed across the shoulder at the top may be pressed down over the side until it drops over the edge of the bone. The acromion makes a shelf above the head of the humerus with a slight depression intervening.

† The sum of the two measurements gives the same distinctions between children as would be obtained by averaging the two measurements, and reduces one step in the computation.

‡ The deltoid measurement with the calipers is included with the girth measurements because it represents a factor so similar to girth of arm.

Ask the child to remove the right sleeve. Girls wearing short, loose sleeves can roll the sleeves up over the shoulder. Have the child seated on a straight chair or stool with right arm extended out from the body toward the table. Support the hand, palm downward, with a block, box or books, so the arm is on a level with the shoulder. Have the child relax the shoulder.

Standing back of the extended arm and facing the child's right, place the end of a flexible celluloid ruler in contact with the acromion process at its midpoint and, extending it along the child's arm toward the elbow, place a mark on the arm, at the right of the ruler, at 2, 3, 4, and 5 centimeters out from the acromion process. Remove the support from under the child's hand, have him hold the arm in the same position and measure the four widths of the arm over the deltoid with the small metal calipers at each mark. Hold the body of the calipers perpendicular to and touching the skin surface and release the sliding arm of calipers entirely so that full pressure of the spring is exercised. Add the four measurements to obtain the deltoid measure.

II. *Girth of Upper Arm* (Two measurements)

Measurements are taken with the steel tape, equipped with Gulick spring handle.* Measure the bare right upper arm with the child standing. Relation of examiner to subject is the same as for deltoid measurements. (If the child is left-handed, measure left arm.)

1. *Arm Flexed.* Ask the child to put the tips of his fingers on his shoulder with the arm extended at right angle to the body. Wait until he does not flex the muscles more than this position would naturally flex them.

With the steel tape, measure the girth of the upper arm at the highest point of the biceps muscle, pulling the Gulick handle of the tape until the tension is sufficient to show the mark † on the wire as it emerges from the handle. Care should be exercised that both the tape and the wire attached to the spring in the handle pull freely against the springs and do not bind at any point. Take reading and hold the tape in place with the left hand for the next measurement.

2. *Arm Relaxed.* With the tape in the same position as for (1), ask the child to drop his arm loosely to the side of the body.

Take measurement using same technique as for (1).

Add the flexed and relaxed readings for the arm girth measure.

* Sold by the Narragansett Machine Company, Providence, Rhode Island.

† The wire attached to the spring in the handle is marked at that point where it emerges from the cylinder of the handle when its spring is pulled out against the tension of the spring in the coil of the instrument until the two are balanced.

III. *Girth of Calf*

Ask the child to roll the left stocking down to the ankle. Measurement is taken on the bare left leg. Use the steel tape as for arm girth. The child is seated on a corner of a table with legs hanging and external surface of the left thigh along the edge of the table.

Stand at the child's left and take the measurement at the largest part of the calf, using the same technique as for the arm girths. Be sure that the leg is relaxed. Before removing the tape make a pencil mark across the calf at the lower margin of the tape.

D. Subcutaneous Tissue Measurements

Measurements taken with special Subcutaneous Tissue Calipers.*

I. *Subcutaneous Tissue over the Biceps* (Two measurements)

Measurement is taken on the bare right upper arm. The relation of examiner to subject is the same as for deltoid and girth of arm.

Landmarks for Measurement. With arm extended out from the body at a level with the shoulder, ask the child to bring the fist to the shoulder, palm downward, completely flexing the muscles of the arm. Mark the highest point on the biceps and have the child relax and lower his arm. From this "biceps point" draw a line, with celluloid ruler as a guide, to posterior surface of arm perpendicular to the length of the arm.

Measurement Number 1. Using the biceps point as a center, straddle the blades of the calipers equally on each side of "biceps point" with the lower edge of the blades on the horizontal line which has been drawn on the arm. Hold caliper blades at 30 to measure size of bite. With the left hand above the calipers, place the palmar surfaces of the left thumb and index finger in contact with the outer surface of the caliper blades and fingers perpendicular to the skin surface of the arm.† The calipers are then removed and the fingers thereby assume a definite position for grasping the underlying tissue. The tissue is pinched up with the fingers to free it from the underlying musculature. The thickness of the subcutaneous tissue is then determined by placing the tips of the caliper blades below, parallel, and in line with the tips of the thumb and forefinger.‡ The pres-

* Arrangements have been made with the Kny Scheerer Company, New York City, for the manufacture of this instrument. Obtainable from the American Child Health Association.

† As the size of the bite of skin pinched up influences the thickness of the double layer of subcutaneous tissue measured, we have devised this method of measuring the position of the fingers to get a constant size of bite.

‡ The absolute measures, of course, include a double layer of skin thickness. But individual differences in skin thickness are so small relative to individual differences in

sure of the spring of the calipers holds the tissue firmly between the blades and the indicator on the scale gives a measure of its thickness. (If the tissues are very firm the calipers will tend to slip, then the blades of the calipers are pressed inward just enough to keep the tips of the blades in line with the left thumb and forefinger.) Record the caliper reading.

Measurement Number 2. The second measurement is made like the first except that to locate the position of the thumb and forefinger, the upper edges of caliper blades are placed on the line drawn on the arm.

The sum of the two readings is the biceps subcutaneous tissue measure.

II. *Subcutaneous Tissue over the Triceps* (Four measurements)

The measurements are made on right arm in the same manner as over the biceps.

Landmarks for Measurement. The landmarks for the triceps subcutaneous tissue measurements are determined by the point of intersection of the line drawn on the arm from the "biceps point" with a line drawn from the midpoint of the acromion process to the olecranon. The vertical line is drawn while the child's hand is on his hip with the thumb toward the back.

Measurement Number 1. Using the vertical intersecting line as a center, straddle the vertical line with the blades of the calipers, with the lower edge of the blades on the horizontal line around the arm. Hold the caliper blades at 40 on the scale, to measure size of bite. With the left hand above the calipers, place the palmar surfaces of the left thumb and index finger in contact with the outer surface of the caliper blades keeping the fingers perpendicular to the skin surface of the arm. The calipers are then removed and the fingers thereby assume a definite position for grasping the underlying tissue. The tissue is pinched up with the fingers to free it from the underlying musculature. The thickness of the tissue is then determined by placing the tips of the caliper blades below, parallel, and in line with the tips of the thumb and forefinger. The pressure of the spring of the calipers holds the tissue firmly between the blades and the indicator on the scale gives a measure of its thickness. (If the tissues are very firm, the calipers will tend to slip, then the blades of the calipers are pressed inward just enough to keep the tips of the blades in line with the left thumb and forefinger.) Record the caliper reading.

Measurement Number 2. The second measurement is made like the first except that the position of the thumb and finger is located by placing the

amount of subcutaneous tissue that discriminations made adequately represent this latter factor.

upper edge of caliper blades on the horizontal line on the arm as in Measurement Number 2 of the subcutaneous tissue over the biceps.

Measurements Numbers 3 and 4. The third measurement is made like the first with the lower edges of the caliper blades on the horizontal line but with the left blade on the vertical line.

The fourth measurement is like the third except that this time the right blade is on the vertical line.

The sum of the four readings gives the triceps subcutaneous tissue measure.

III. *Subcutaneous Tissue over the Calf* (Four measurements)

Measure left leg with child seated on table as for girth of calf.

Landmarks for Measurement. Use as the horizontal line, the line previously drawn across the calf, following the girth of calf measurement. Draw vertical line from the center of the popliteal space downward so following the line of the lower leg that it intersects the horizontal. The four measurements are taken above and below the horizontal line and in the external and internal side of the vertical line above the horizontal line as over the triceps. Hold the caliper blades at 40 on the scale, to measure size of bite.

The sum of these four measurements gives the calf subcutaneous tissue measure.

Order of Making Measurements

The order of measurements in the foregoing procedure is followed for convenience of description. In the routine of making the measurements it saved time and was more convenient to use the following order: (1) Weight; (2) height; (3) shoulder breadth; (4) chest breadth; (5) chest depth; (6) hip breadth; (7) deltoid; (8) girth of upper arm, (a) flexed, (b) relaxed; (9) subcutaneous tissue over the biceps, measurements numbers one and two; (10) subcutaneous tissue over the triceps, measurements numbers one, two, three, and four; (11) calf girth; (12) subcutaneous tissue over the calf, measurements numbers one, two, three, and four.

Appendix B

BASIC DATA

Table A

INTERCORRELATIONS OF TWELVE ANTHROPOMETRIC CHARACTERISTICS IN TEN-YEAR-OLD GIRLS

Number of Cases 909

	Weight	Height	Bisacromial Width	Breadth of Chest	Depth of Chest	Width of Hips	Size of Deltoid Muscle	Girth of Upper Arm	Girth of Calf	Amount of Subcutaneous Tissue over Calf	Amount of Subcutaneous Tissue over Biceps	Amount of Subcutaneous Tissue over Triceps
Height	.72											
Bisacromial Width	.71	.70										
Breadth of Chest	.80	.58	.72									
Depth of Chest	.79	.50	.51	.67								
Width of Hips	.85	.68	.68	.68	.67							
Size of Deltoid Muscle	.82	.49	.60	.67	.67	.71						
Girth of Upper Arm	.87	.44	.54	.69	.72	.72	.86					
Girth of Calf	.86	.54	.57	.67	.68	.73	.73	.81				
Amount of Subcutaneous Tissue over the Calf	.47	.28	.23	.42	.45	.33	.33	.46	.49			
Amount of Subcutaneous Tissue over the Biceps	.56	.23	.25	.43	.49	.45	.48	.66	.49	.56		
Amount of Subcutaneous Tissue over the Triceps	.55	.17	.20	.38	.42	.46	.52	.68	.54	.50	.81	
Mean	71.1	54.4	29.4	41.4	30.6	24.7	23.3	38.9	27.8	106.7	29.7	85.8
Sigma	12.5	2.5	1.5	2.8	2.6	1.7	2.3	4.1	2.2	12.6	4.9	12.8

Table B

INTERCORRELATIONS OF TWELVE ANTHROPOMETRIC CHARACTERISTICS IN TEN-YEAR-OLD BOYS

Number of Cases 788

	Weight	Height	Bisacromial Width	Breadth of Chest	Depth of Chest	Width of Hips	Size of Deltoid Muscle	Girth of Upper Arm	Girth of Calf	Amount of Subcutaneous Tissue over Calf	Amount of Subcutaneous Tissue over Biceps	Amount of Subcutaneous Tissue over Triceps
Height	.75											
Bisacromial Width	.71	.68										
Breadth of Chest	.78	.58	.73									
Depth of Chest	.70	.47	.43	.54								
Width of Hips	.82	.66	.63	.65	.57							
Size of Deltoid Muscle	.76	.50	.59	.63	.57	.64						
Girth of Upper Arm	.87	.46	.56	.68	.66	.70	.80					
Girth of Calf	.84	.55	.57	.64	.60	.67	.67	.79				
Amount of Subcutaneous Tissue over the Calf	.44	.25	.21	.37	.35	.27	.23	.43	.45			
Amount of Subcutaneous Tissue over the Biceps	.62	.28	.31	.44	.48	.51	.44	.68	.55	.57		
Amount of Subcutaneous Tissue over the Triceps	.60	.25	.29	.41	.41	.51	.43	.66	.55	.53	.85	
Mean	71.7	54.5	29.7	42.3	31.2	24.5	24.4	38.8	27.4	101.0	25.8	74.2
Sigma	11.0	2.3	1.5	2.5	2.2	1.5	2.2	3.7	2.0	14.5	4.5	13.0

Table C

INTERCORRELATIONS OF TWELVE ANTHROPOMETRIC CHARACTERISTICS IN ELEVEN-YEAR-OLD GIRLS

Number of Cases 1000

	Weight	Height	Bisacromial Width	Breadth of Chest	Depth of Chest	Width of Hips	Size of Deltoid Muscle	Girth of Upper Arm	Girth of Calf	Amount of Subcutaneous Tissue over Calf	Amount of Subcutaneous Tissue over Biceps	Amount of Subcutaneous Tissue over Triceps
Height	.74											
Bisacromial Width	.72	.72										
Breadth of Chest	.83	.63	.76									
Depth of Chest	.82	.54	.53	.68								
Width of Hips	.88	.73	.71	.73	.70							
Size of Deltoid Muscle	.85	.53	.63	.72	.74	.75						
Girth of Upper Arm	.89	.51	.58	.73	.78	.74	.86					
Girth of Calf	.88	.57	.61	.71	.73	.76	.78	.84				
Amount of Subcutaneous Tissue over the Calf	.49	.31	.27	.44	.47	.34	.37	.49	.50			
Amount of Subcutaneous Tissue over the Biceps	.57	.24	.24	.44	.49	.43	.49	.65	.52	.62		
Amount of Subcutaneous Tissue over the Triceps	.55	.20	.23	.41	.44	.44	.50	.66	.53	.54	.83	
Mean	77.9	56.2	30.3	42.9	31.8	25.8	24.3	40.1	28.7	108.9	30.0	85.7
Sigma	15.6	2.8	1.9	3.1	3.0	2.0	2.5	4.6	2.6	13.6	5.1	13.3

Table D

INTERCORRELATIONS OF TWELVE ANTHROPOMETRIC CHARACTERISTICS IN ELEVEN-YEAR-OLD BOYS

Number of Cases 1000

	Weight	Height	Bisacromial Width	Breadth of Chest	Depth of Chest	Width of Hips	Size of Deltoid Muscle	Girth of Upper Arm	Girth of Calf	Amount of Subcutaneous Tissue over Calf	Amount of Subcutaneous Tissue over Biceps	Amount of Subcutaneous Tissue over Triceps
Height	.72											
Bisacromial Width	.63	.61										
Breadth of Chest	.76	.54	.60									
Depth of Chest	.71	.40	.37	.54								
Width of Hips	.82	.65	.58	.63	.56							
Size of Deltoid Muscle	.80	.49	.53	.65	.64	.67						
Girth of Upper Arm	.88	.46	.48	.67	.69	.69	.83					
Girth of Calf	.87	.52	.50	.64	.63	.71	.71	.84				
Amount of Subcutaneous Tissue over the Calf	.50	.26	.22	.39	.41	.34	.32	.49	.54			
Amount of Subcutaneous Tissue over the Biceps	.66	.27	.27	.50	.52	.49	.49	.70	.62	.61		
Amount of Subcutaneous Tissue over the Triceps	.61	.23	.22	.42	.43	.48	.47	.68	.61	.55	.85	
Mean	76.3	55.6	30.3	43.5	31.9	25.1	25.2	39.8	28.0	103.0	25.8	74.7
Sigma	12.1	2.4	1.7	2.6	2.3	1.6	2.3	4.0	2.1	15.3	4.6	13.4

Table E

INTERCORRELATIONS OF TWELVE ANTHROPOMETRIC CHARACTERISTICS IN TWELVE-YEAR-OLD GIRLS

Number of Cases 500

	Weight	Height	Bisacromial Width	Breadth of Chest	Depth of Chest	Width of Hips	Size of Deltoid Muscle	Girth of Upper Arm	Girth of Calf	Amount of Subcutaneous Tissue over Calf	Amount of Subcutaneous Tissue over Biceps	Amount of Subcutaneous Tissue over Triceps
Height	.72											
Bisacromial Width	.78	.73										
Breadth of Chest	.86	.58	.77									
Depth of Chest	.79	.47	.53	.71								
Width of Hips	.88	.72	.76	.77	.66							
Size of Deltoid Muscle	.83	.52	.68	.74	.67	.74						
Girth of Upper Arm	.91	.51	.65	.79	.77	.76	.87					
Girth of Calf	.91	.61	.71	.77	.72	.80	.78	.86				
Amount of Subcutaneous Tissue over the Calf	.46	.31	.28	.40	.41	.32	.25	.43	.47			
Amount of Subcutaneous Tissue over the Biceps	.58	.31	.33	.45	.50	.44	.43	.63	.54	.58		
Amount of Subcutaneous Tissue over the Triceps	.58	.28	.31	.45	.45	.46	.49	.65	.55	.49	.82	
Mean	84.5	57.6	31.2	44.2	32.8	27.0	25.3	41.2	29.4	107.3	28.7	83.3
Sigma	16.8	2.7	1.9	3.5	3.3	2.2	2.7	4.7	2.7	14.2	4.8	13.0

Table F

INTERCORRELATIONS OF TWELVE ANTHROPOMETRIC CHARACTERISTICS IN TWELVE-YEAR-OLD BOYS

Number of Cases 600

	Weight	Height	Bisacromial Width	Breadth of Chest	Depth of Chest	Width of Hips	Size of Deltoid Muscle	Girth of Upper Arm	Girth of Calf	Amount of Subcutaneous Tissue over Calf	Amount of Subcutaneous Tissue over Biceps	Amount of Subcutaneous Tissue over Triceps
Height	.74											
Bisacromial Width	.74	.71										
Breadth of Chest	.79	.60	.74									
Depth of Chest	.75	.47	.48	.61								
Width of Hips	.85	.70	.71	.71	.65							
Size of Deltoid Muscle	.82	.57	.67	.70	.67	.76						
Girth of Upper Arm	.89	.51	.61	.72	.75	.76	.85					
Girth of Calf	.89	.61	.65	.71	.69	.76	.76	.85				
Amount of Subcutaneous Tissue over the Calf	.43	.24	.21	.36	.39	.30	.29	.45	.47			
Amount of Subcutaneous Tissue over the Biceps	.60	.28	.26	.44	.56	.49	.49	.68	.56	.61		
Amount of Subcutaneous Tissue over the Triceps	.56	.22	.24	.39	.49	.48	.46	.64	.53	.56	.85	
Mean	82.9	57.2	31.2	44.6	33.0	26.0	26.2	41.2	28.9	103.0	25.8	74.1
Sigma	15.2	2.8	1.8	3.0	2.8	1.8	2.5	4.5	2.5	16.2	4.7	14.3

Table G

ALL OF THE SKELETAL MULTIPLE CORRELATIONS WITH WEIGHT
1100 ELEVEN-YEAR-OLD GIRLS

Height	Chest Depth	Chest Breadth	Hips	Number of Variables			
				One	Two	Three	Four
X				.72			
	X			.82			
		X		.83			
			X	.87			
X		X			.88		
X			X		.88		
X	X				.89		
	X	X			.90		
	X		X		.92		
		X	X		.92		
X	X	X				.92	
X		X	X			.92	
X	X		X			.93	
	X	X	X			.94	
X	X	X	X				.9441

Table H

ALL OF THE SKELETAL MULTIPLE CORRELATIONS WITH WEIGHT
500 ELEVEN-YEAR-OLD BOYS *

Height	Chest Depth	Chest Breadth	Hips	Number of Variables			
				One	Two	Three	Four
	X			.70			
X				.72			
		X		.77			
			X	.82			
X		X			.84		
	X	X			.84		
X	X				.85		
X			X		.85		
	X		X		.88		
		X	X		.88		
X	X	X				.89	
X		X	X			.89	
X	X		X			.90	
	X	X	X			.90	
X	X	X	X				.9208

* These multiples were computed on the first five hundred cases gathered. Data in Table 8 indicate that the results would be the same if this data had been computed on one thousand.

Table I

EQUATIONS TO OBTAIN EXPECTATION OF ARM GIRTH, CALF GIRTH, AND BICEPS SUBCUTANEOUS TISSUE BY AGE AND SEX GROUPS

Regression Equations to Predict Arm Girth

Ten-Year-Old Girls

Expectation of Arm Girth = —.287 Ht. + .421 Ch. Br. + .553 Ch. D. + .994 Hips — 4.46

Eleven-Year-Old Girls

Expectation of Arm Girth = —.270 Ht. + .398 Ch. Br. + .687 Ch. D. + .811 Hips — 6.65

Twelve-Year-Old Girls

Expectation of Arm Girth = —.155 Ht. + .457 Ch. Br. + .501 Ch. D. + .715 Hips — 5.77

Ten-Year-Old Boys

Expectation of Arm Girth = —.221 Ht. + .505 Ch. Br. + .558 Ch. D. + .972 Hips — 11.81

Eleven-Year-Old Boys

Expectation of Arm Girth = —.092 Ht. + .433 Ch. Br. + .632 Ch. D. + .836 Hips — 14.98

Twelve-Year-Old Boys

Expectation of Arm Girth = —.182 Ht. + .402 Ch. Br. + .595 Ch. D. + 1.022 Hips — 12.49

Regression Equations to Predict Calf Girth

Ten-Year-Old Girls

Expectation of Calf Girth = .003 Ht. + .169 Ch. Br. + .225 Ch. D. + .513 Hips + 1.12

Eleven-Year-Old Girls

Expectation of Calf Girth = —.030 Ht. + .168 Ch. Br. + .280 Ch. D. + .529 Hips + .61

Twelve-Year-Old Girls

Expectation of Calf Girth = .067 Ht. + .190 Ch. Br. + .206 Ch. D. + .462 Hips — 2.13

Ten-Year-Old Boys

Expectation of Calf Girth = .070 Ht. + .214 Ch. Br. + .225 Ch. D. + .412 Hips — 2.62

Eleven-Year-Old Boys

Expectation of Calf Girth = .032 Ht. + .185 Ch. Br. + .250 Ch. D. + .516 Hips — 2.70

Twelve-Year-Old Boys

Expectation of Calf Girth = .086 Ht. + .196 Ch. Br. + .226 Ch. D. + .483 Hips — 4.75

Regression Equations to Predict Biceps Subcutaneous Tissue

Ten-Year-Old Girls

Expectation of Biceps Subcutaneous Tissue
= —.258 Ht. — .656 Bisac. + .456 Ch. Br. + .504 Ch. D. + .964 Hips + 4.82

Table I

Continued

Eleven-Year-Old Girls

Expectation of Biceps Subcutaneous Tissue
= —.262 Ht. — .624 Bisac. + .481 Ch. Br. + .517 Ch. D. + .673 Hips + 9.24

Twelve-Year-Old Girls

Expectation of Biceps Subcutaneous Tissue
= .062 Ht. — .357 Bisac. + .262 Ch. Br. + .449 Ch. D. + .391 Hips — 0.59

Ten-Year-Old Boys

Expectation of Biceps Subcutaneous Tissue
= —.305 Ht. — .281 Bisac. + .395 Ch. Br. + .520 Ch. D. + 1.182 Hips — 11.10

Eleven-Year-Old Boys

Expectation of Biceps Subcutaneous Tissue
= —.238 Ht. — .278 Bisac. + .495 Ch. Br. + .585 Ch. D. + .830 Hips — 13.56

Twelve-Year-Old Boys

Expectation of Biceps Subcutaneous Tissue
= —.087 Ht. — .720 Bisac. + .325 Ch. Br. + .606 Ch. D. + .853 Hips — 3.46

Appendix C

STATISTICAL TECHNIQUE

Appendix C

STATISTICAL TECHNIQUE

1. *Correlation*

Throughout this monograph the method used for expressing the relationship between two variables was the Pearson product moment formula for correlation:

$$r_{xy} = \frac{\Sigma xy}{N\sigma_x\sigma_y} *$$

The most important assumption on which this formula is based, that of rectilinearity, has been met in the relationships here reported. Confining the relations to age spans of not over 12 months prohibited such curvilinearity as might have been encountered had the relations been computed on age spans covering the entire period.

In actual computation we used a modification of the above formula which allows the use of crude records instead of deviations from the means and also provides automatic checks on each step in the computation, thus assuring entire accuracy. The formula used was

$$r_{xy} = \frac{\frac{\Sigma XY}{N} - M_x M_y}{\sqrt{\frac{\Sigma(X^2)}{N} - M_x^2}\sqrt{\frac{\Sigma(Y^2)}{N} - M_y^2}}$$

where X and Y are the crude scores and M_x and M_y are the means of the two traits. The checks used are those described by Hull in "Aptitude Testing" and are outlined here. The six crude moments required in the formula are N, ΣX, ΣY, ΣX^2, ΣY^2 and ΣXY. To check N, the number of cases was counted independently by two workers. (Check 1)

The measures were listed in columns, the X measure for any individual opposite the Y measure. A third column, which we will call A, was obtained by summing the X's and Y's for each individual. Then

$$\Sigma X + \Sigma Y = \Sigma A \qquad \text{(Check 2)}$$

Since $(a + b)^2 = a^2 + b^2 + 2ab$ and the summation sign is distributive,

$$\Sigma(A^2) = \Sigma(X^2) + \Sigma(Y^2) + 2\Sigma(XY) \qquad \text{(Check 3)}$$

* x and y are here used to express deviations from the means of the X and Y traits.

Form I *

N—— Var. No.	(a)	(b)	(c)	(d)	(e)	(f)	(g)
	Copy from Data Sheet	(a)/N	(b)²	Copy from Data Sheet	d/n	e — c	√(f)
	Σ A	M A	(M A)²	Σ A²	M A²	σ^2	σ
	(1)	(4)	(7)	(2)	(5)	(8)	(9)
Totals							
	Total a divided by N			Total d divided by N			Total e—Total c

Total c + 2 × Total O —— = —— (Total b)²

Total f + 2 × Total K —— = —— (Total g)²

Form II *

N—— Comb. of Vars.	(h)	(i)	(k)	(l)	(m)	(o)	(p)	(r)	(s)	(t)
	Copy from Sheet I		(h) × (i)	Copy from Sheet I		(l) × (m)	Copy Data Sheet	(p)/N	(r) — (o)	(s)/(k)
	σA	σB	σA × σB	M A	M B	MA · MB	Σ A B	M A · B	Num.	r
	(10)	(11)	(14)	(12)	(13)	(15)	(3)	(6)	(16)	(17)
Totals										
						Total (p) divided by N				Total (r) minus Total (o)

* Adapted from Hull's "Aptitude Testing," Copyright, 1928, by World Book Company, Yonkers-on-Hudson, New York.

Both Check 2 and Check 3 can be more generally stated for intercorrelations thus:

$$\Sigma(X_1) + \Sigma(X_2) + \ldots . \Sigma(X_n) = \Sigma(A) \qquad \text{(Check 2)}$$

$$\Sigma(X_1^2) + \Sigma(X_2^2) + \ldots . \Sigma(X_n^2) + 2\Sigma(X_1 X_2) + 2\Sigma(X_1 X_3) + \ldots . 2\Sigma(X_{n-1} X_n) = \Sigma(A^2) \qquad \text{(Check 3)}$$

The checks on the computation of the r from these crude moments are shown on the two accompanying forms which are modifications of those used by Dr. Hull and reprinted here. These forms are most useful when intercorrelations are being computed. However, the checks are just as applicable to the situation where only one r is wanted.

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$$\text{Standard Difference} = \frac{M_x - M_y}{\sqrt{\frac{\sigma_x^2}{n_x} + \frac{\sigma_y^2}{n_y}}}$$

Please substitute above formula for that given under *Standard Differences.*

3. *Multiple Correlation and Regression*

A dependent trait X_1 may be estimated from several independent traits $X_2, X_3, \ldots . X_n$ when these traits are all linearly related by means of the multiple regression equation:

$$\overline{X}_1 = b_{12.34\ldots n} X_2 + b_{13.24\ldots n} X_3 + \ldots . + b_{1n.23\ldots(n-1)} X_n + K \dagger$$

* M_x is mean of satisfactory group, M_y is mean of unsatisfactory group, σ_x and σ_y are the standard deviations for the two groups. Because we are comparing two distinct groups the r between the two means may be considered as zero and hence does not appear in the formula.

† Yule, "Introduction to the Theory of Statistics," p. 247.

where the coefficients of $X_2, X_3 \ldots . X_n$ are determined from the solution of a set of normal equations in such a way that the standard error of the errors in estimating X_1 by the use of this equation shall be a minimum. The relation of the estimated $\overline{X}_1$ to the actual X_1 as measured is the multiple correlation coefficient. It may be computed as a byproduct of the solution of the normal equations or by the formula

$$R_{1(23\ldots n)} = \sqrt{1-(1-r_{12}^2)\,(1-r_{13.2}^2)\ldots .\,(1-r_{1n.23\ldots(n-1)}^2)}$$

4. *Coefficients of Standard Scores in the Multiple Regression Equation*

The b's described in the previous section are of course coefficients for deviations in crude scores. They are used to get predictions like those in Table X of Chapter IV.

We have developed in Chapters I, II, and III, amounts of "Emphasis" given to each of a number of traits in medical ratings, predictions of weight, and predictions of girth. We used β's as indices of this emphasis.*

When comparison is made of two or more traits, they are rendered biologically comparable by relating each to the average and variability of the same group of individuals $\left(\frac{X-M_x}{\sigma_x}\right)$. This is called a standard score. We may write our multiple regression equation using standard scores.

$$\frac{\overline{X}_1}{\sigma_1} = \beta_{12.34\ldots n}\frac{X_2}{\sigma_2} + \beta_{13.24\ldots n}\frac{X_3}{\sigma_3} + \ldots . + \beta_{1n.23\ldots(n-1)}\frac{X_n}{\sigma_n}$$

This equation follows directly from the other since

$$b_{12.34\ldots n} = \beta_{12.34\ldots n}\frac{\sigma_1}{\sigma_2}$$

We see then that the β's are coefficients in prediction equations using only standard scores. They therefore give the emphasis of traits irrespective of arbitrary units of measurements and unlocated zeros.

5. *Standard Score Residuals*

Residuals should be comparable. For this reason they must be stated as standard scores and also in order to translate them into probable frequency of occurrence. The following formula achieves this purpose:

$$\frac{X_1 - [b_{12.34\ldots n}X_2 + b_{13.24\ldots n}X_3 + \ldots . + b_{1n.23\ldots(n-1)}X_n + K]}{\sigma_1\sqrt{1-R_{1\,(23\ldots n)}^2}}$$

* Kelley, "Statistical Method," p. 295.

The second term in the numerator of this equation is represented for various predictions in Table X. The denominators are listed in Table Y. A rough translation of result and standard scores into the frequency with which a standard score of its size occurs (counting both positive and negative occurrence) is given in Table Z.

6. *Correlation of Gross Scores with Residuals* *

Correlation is a measure of the association of standard scores in two variables. The correlation formula may be written in this form:

$$r_{xy} = \frac{\Sigma\left(\frac{x}{\sigma_x} \cdot \frac{y}{\sigma_y}\right)}{N}$$

Partial correlation may be written in this form also:

$$r_{xy.z} = \frac{\Sigma\left(\frac{X - r_{xz}\frac{\sigma_x}{\sigma_z}Z}{\sigma_x\sqrt{1 - r_{xz}^2}}\right)\left(\frac{Y - r_{yz}\frac{\sigma_y}{\sigma_z}Z}{\sigma_y\sqrt{1 - r_{yz}^2}}\right)}{N}$$

This reduces to the ordinary partial

$$r_{xy.z} = \frac{r_{xy} - r_{xz}\,r_{yz}}{\sqrt{1 - r_{xz}^2}\sqrt{1 - r_{yz}^2}}$$

We may correlate a zero order standard score $\left(\frac{z}{\sigma_z}\right)$ with a residual standard score $\left(\frac{X - r_{xy}\frac{\sigma_x}{\sigma_y}y}{\sigma_x\sqrt{1 - r_{xy}^2}}\right)$. This gives the following:

$$r_{(x.y)z} = \frac{r_{xz} - r_{yz}\,r_{xy}}{\sqrt{1 - r_{xy}^2}}$$

We may also correlate two residual standard scores where the control is different, like weight irrespective of height with arm girth irrespective of hips. The formula is:

$$r_{(x.w)(y.z)} = \frac{r_{xy} - r_{xz}\,r_{yz} - r_{yw}\,r_{xw} + r_{zw}\,r_{xw}\,r_{yz}}{\sqrt{1 - r_{xw}^2}\,\sqrt{1 - r_{yz}^2}}$$

Similar formulæ involving higher order residuals were derived in this same manner. They were used in the text as designated.

* Raymond Franzen, "A Comment on Partial Correlation," Journal of Educational Psychology, March, 1928.

7. *Use of R^2 When Comparing Multiple Correlations*

Using correlations between zero order standard scores and residual standard scores we may show that:

$$R_{1.234}{}^2 = r_{12}{}^2 + r_{1\,(3.2)}{}^2 + r_{1(4.23)}{}^2$$

It may also be shown that:

$$R_{1.234}{}^2 - R_{1.23}{}^2 = r_{1(4.23)}{}^2$$

Proof of these formulæ and further expansions are in our files and will be published in the near future.

8. *Use of Means of One Age-Sex Group in the Regressions of Another*

The technique is the substitution of the M's of one group in the regression of another. When this brings a prediction like the true mean with .5 of an error of estimate we conclude that the relations (including compensation of the variables involved) are alike in the two groups.

The assumptions involved in this conclusion are as follows: (1) that the ratio of σ's of the variables is like the ratio of the M's; (2) that the zero order correlations between the variables are positive and high.

As far as these two assumptions hold we can of course get the same results for individuals situated at any position in the curves that we get with the M's.

9. *Linearity of Relation*

We give below η and r for each of the important variables with weight. We have used linear regressions throughout this study because the differences between η and r given below did not seem large enough to justify a curve fitting technique. Furthermore, we have a multiple correlation of .98 with weight which would be impossible if curvilinearity of an important correlate was significant.

Correlation Coefficients and Correlation Ratios for Traits with Weight

x	r	$\eta_{wt\ x}$	$\eta_{x\ wt}$
Height	.72	.74	.77
Chest Breadth	.76	.76	.80
Chest Depth	.71	.72	.73
Hips	.82	.83	.85
Deltoid	.80	.80	.81
Arm Girth	.88	.89	.89
Calf Girth	.87	.87	.89
Biceps Subcutaneous Tissue	.66	.69	.68
Triceps Subcutaneous Tissue	.61	.64	.64

10. *Omission of Probable Errors of r's*

$P.E._r = \frac{\sqrt{1 - r^2}}{N}$. This is the sampling error of r and does not involve errors of measurement, recording and interfering uncontrolled variables. Two r's of .70 each with an N of 1000 may have entirely different chance of being other than .70 in another group of 1000 under the same conditions as far as it is under the examiner's control. This is because the variables have entirely different errors of measurement. We believe that $P.E._r$ has been interpreted by readers to mean the chances that the r will diverge in data gathered in the same way. We wish to avoid such a misinterpretation on the part of our readers. Sampling errors of r must be negligible if the N is adequate.

Appendix D

SUPPLEMENTARY DATA

Table J–1

MEANS OF EACH OF EIGHT TRAITS FOR EACH AGE-SEX GROUP

	Girls			Boys		
Age	10	11	12	10	11	12
Height	54.4	56.2	57.6	54.5	55.6	57.2
Chest Breadth	41.4	42.9	44.2	42.3	43.5	44.6
Chest Depth	30.6	31.8	32.8	31.2	31.9	33.0
Hip Width	24.7	25.8	27.0	24.5	25.1	26.0
Arm Girth	38.9	40.1	41.2	38.8	39.8	41.2
Calf Girth	27.8	28.7	29.4	27.4	28.0	28.9
Biceps Subcutaneous Tissue	29.7	30.0	28.7	25.8	25.8	25.8
Triceps Subcutaneous Tissue	85.8	85.7	83.3	74.2	74.7	74.1

Table J–2

SIGMAS OF EACH OF EIGHT TRAITS FOR EACH AGE-SEX GROUP

	Girls			Boys		
Age	10	11	12	10	11	12
Height	2.5	2.8	2.7	2.3	2.4	2.8
Chest Breadth	2.8	3.1	3.5	2.5	2.6	3.0
Chest Depth	2.6	3.0	3.3	2.2	2.3	2.8
Hip Width	1.7	2.0	2.2	1.5	1.6	1.8
Arm Girth	4.1	4.6	4.7	3.7	4.0	4.5
Calf Girth	2.2	2.6	2.7	2.0	2.1	2.5
Biceps Subcutaneous Tissue	4.9	5.1	4.8	4.5	4.6	4.7
Triceps Subcutaneous Tissue	12.8	13.3	13.0	13.0	13.4	14.3

Table J–3

DATA FOR THE DETERMINATION OF THE EXPECTATION OF EIGHT SELECTED MEASURES FROM EACH OF THE OTHER SEVEN

COEFFICIENTS OF STANDARD SCORES IN THE MULTIPLE REGRESSION EQUATION FOR HEIGHT

	Girls			Boys		
Age	10	11	12	10	11	12
Chest Breadth	.223	.206	.107	.260	.220	.197
Chest Depth	.045	.060	—.026	.111	.002	.009
Hip Width	.587	.660	.664	.492	.522	.580
Arm Girth	—.207	—.217	—.277	—.240	—.068	—.309
Calf Girth	.177	.105	.265	.248	.176	.338
Biceps Subcutaneous Tissue	.077	.055	.123	—.022	—.025	.114
Triceps Subcutaneous Tissue	—.225	—.165	—.132	—.110	—.156	—.220
Multiple Correlation of Seven Traits with Height	.730	.752	.743	.720	.691	.750

COEFFICIENTS OF STANDARD SCORES IN THE MULTIPLE REGRESSION EQUATION FOR CHEST BREADTH

	Girls			Boys		
Age	10	11	12	10	11	12
Height	.185	.168	.069	.233	.193	.175
Chest Depth	.187	.121	.162	.038	.063	.098
Hip Width	.138	.206	.279	.157	.171	.191
Arm Girth	.335	.345	.379	.371	.316	.337
Calf Girth	.111	.106	.098	.120	.100	.148
Biceps Subcutaneous Tissue	.096	.037	—.014	.034	.193	—.014
Triceps Subcutaneous Tissue	—.164	—.083	—.060	—.084	—.177	—.070
Multiple Correlation of Seven Traits with Chest Breadth	.783	.804	.843	.753	.736	.782

COEFFICIENTS OF STANDARD SCORES IN THE MULTIPLE REGRESSION EQUATION FOR CHEST DEPTH

	Girls			Boys		
Age	10	11	12	10	11	12
Height	.037	.044	—.021	.118	.002	.009
Chest Breadth	.183	.109	.208	.045	.068	.104
Hip Width	.172	.151	.075	.097	.119	.142
Arm Girth	.358	.512	.453	.398	.470	.428
Calf Girth	.147	.104	.126	.125	.096	.079
Biceps Subcutaneous Tissue	.179	.146	.157	.198	.232	.184
Triceps Subcutaneous Tissue	—.201	—.177	—.159	—.191	—.225	—.097
Multiple Correlation of Seven Traits with Chest Depth	.788	.825	.794	.699	.715	.768

COEFFICIENTS OF STANDARD SCORES IN THE MULTIPLE REGRESSION EQUATION FOR HIP WIDTH

	Girls			Boys		
Age	10	11	12	10	11	12
Height	.365	.368	.342	.354	.349	.352
Chest Breadth	.104	.141	.223	.126	.130	.131
Chest Depth	.132	.115	.047	.066	.085	.092
Arm Girth	.197	.170	.175	.254	.149	.292
Calf Girth	.176	.224	.238	.088	.227	.130
Biceps Subcutaneous Tissue	—.056	—.084	—.085	—.005	—.074	—.125
Triceps Subcutaneous Tissue	.125	.103	.073	.131	.137	.157
Multiple Correlation of Seven Traits with Hip Width	.842	.871	.877	.808	.806	.857

COEFFICIENTS OF STANDARD SCORES IN THE MULTIPLE REGRESSION EQUATION FOR ARM GIRTH

	Girls			Boys		
Age	10	11	12	10	11	12
Height	—.086	—.080	—.095	—.112	—.026	—.114
Chest Breadth	.167	.156	.201	.193	.136	.141
Chest Depth	.182	.257	.188	.175	.189	.169
Hip Width	.131	.113	.117	.165	.084	.178
Calf Girth	.356	.358	.415	.354	.431	.445
Biceps Subcutaneous Tissue	.102	.076	.063	.164	.110	.169
Triceps Subcutaneous Tissue	.219	.189	.164	.117	.144	.060
Multiple Correlation of Seven Traits with Arm Girth	.898	.916	.920	.880	.896	.916

COEFFICIENTS OF STANDARD SCORES IN THE MULTIPLE REGRESSION EQUATION FOR CALF GIRTH

	Girls			Boys		
Age	10	11	12	10	11	12
Height	.105	.058	.117	.165	.085	.168
Chest Breadth	.080	.072	.067	.089	.055	.083
Chest Depth	.108	.078	.067	.078	.049	.042
Hip Width	.168	.221	.204	.082	.164	.106
Arm Girth	.511	.535	.533	.505	.553	.597
Biceps Subcutaneous Tissue	—.145	—.023	—.004	—.069	—.008	—.039
Triceps Subcutaneous Tissue	.137	.022	.019	.125	.101	.045
Multiple Correlation of Seven Traits with Calf Girth	.850	.872	.896	.824	.864	.885

COEFFICIENTS OF STANDARD SCORES IN THE MULTIPLE REGRESSION EQUATION FOR AMOUNT OF SUBCUTANEOUS TISSUE OVER BICEPS

	Girls			Boys		
Age	10	11	12	10	11	12
Height	.049	.035	.084	—.011	—.011	.062
Chest Breadth	.074	.029	—.015	.019	.097	—.008
Chest Depth	.141	.128	.130	.094	.110	.105
Hip Width	—.058	—.098	—.112	—.004	—.049	—.110
Arm Girth	.157	.134	.125	.177	.130	.246
Calf Girth	—.156	—.027	—.006	—.052	—.008	—.042
Triceps Subcutaneous Tissue	.722	.723	.716	.723	.708	.708
Multiple Correlation of Seven Traits with Amount of Subcutaneous Tissue over Biceps	.837	.848	.833	.870	.877	.875

COEFFICIENTS OF STANDARD SCORES IN THE MULTIPLE REGRESSION EQUATION FOR AMOUNT OF SUBCUTANEOUS TISSUE OVER TRICEPS

	Girls			Boys		
Age	10	11	12	10	11	12
Height	—.129	—.102	—.086	—.057	—.073	—.129
Chest Breadth	—.113	—.063	—.060	—.049	—.094	—.047
Chest Depth	—.141	—.149	—.125	—.094	—.112	—.060
Hip Width	.115	.114	.092	.095	.096	.152
Arm Girth	.303	.316	.312	.130	.178	.095
Calf Girth	.132	.024	.028	.098	.097	.053
Biceps Subcutaneous Tissue	.646	.691	.682	.744	.745	.773
Multiple Correlation of Seven Traits with Amount of Subcutaneous Tissue over Triceps	.856	.856	.842	.866	.870	.862

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